MAILAM ENGINEERING COLLEGE
Mailam(po),Villupuram(dt.) Pin: 604 304
(Approved by AICTE, New Delhi, Affiliated to Anna University Chennai & Accredited by TCS)
Department of Electrical & Electronics Engineering

SUB CODE / NAME: ME6701/ POWER PLANT ENGINEERING
YEAR / SEC : III/A & B

SYLLABUS

UNIT I COAL BASED THERMAL POWER PLANTS
Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers, Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.

UNIT II DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS
Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.

UNIT III NUCLEAR POWER PLANTS
Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors : Boiling *Water Reactor* (BWR), *Pressurized Water Reactor* (PWR), CANada Deuterium- Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.

UNIT IV POWER FROM RENEWABLE ENERGY
Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, *Solar* Photo Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.

UNIT V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS
Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.

TEXT BOOKS:

1. Nag. P.K., "Power Plant Engineering", Third Edition, Tata McGraw – Hill Publishing Company Ltd., 2008.

REFERENCES:

1.El-Wakil. M.M., "Power Plant Technology", Tata McGraw – Hill Publishing Company Ltd.,2010.
2. Godfrey Boyle, "Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.
2. Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, "Power Plant Engineering", Second Edition, Standard Handbook of McGraw – Hill, 1998.

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PART A

1. State thermodynamic law

- ❖ Zeroth law refers to thermodynamic equilibrium and temperature
- ❖ First law refers to heat, work and energy
- ❖ Second law refers to entropy

2. State zeroth law of thermodynamics:

"Two systems in thermal equilibrium with a third system are in thermal equilibrium with each other"

3. State First law of thermodynamics and energy conversion.

❖ The first law of thermodynamics is often called as Law of conversion of energy. This law suggests that energy can be transferred from one system to another in many forms. Also, it cannot be destroyed or created.

4. State second and third law of thermodynamics:

❖ The second law of thermodynamics another state variable called entropy.
In any closed system, the entropy of the system will either a thermodynamic process, the system can never completely return precisely the same state it was in before.

❖ The third law of thermodynamics states that if all the thermal motion of molecules (kinetic energy) could be removed, a state called absolute zero will occur. Absolute zero results in a temperature of 0 Kelvin or -273.15 Celsius.

5. What is thermodynamic cycle? Or Explain basic thermodynamics cycles? (Nov/Dec14)

❖ A Thermodynamic cycle is a series of thermodynamic processes transferring heat and work, while varying pressure, temperature, and other state variables, eventually returning a system to its initial state.

6. List the various thermodynamic processes:

1. Adiabatic process- a process with no heat transfer into or out of the system
2. Isochoric process- a process with no change in volume, in such case the system does no work
3. Isobaric process- a process with no change in pressure
4. Isothermal process- a process with no change in temperature

7. What is meant by power plant?

❖ Power can be defined as the rate of flow of energy and state that a power plant is a unit built for production and delivery of a flow of mechanical work and electrical energy. A machine or assembling of equipment that produces and delivers a flow of mechanical and electrical energy is a power plant.

8. List the factors of power plant performance.

- ❖ The performance of a power plant can be expressed through some common performance factors as
- ➢ Heat rate
- ➢ Capacity factor
- ➢ Economic efficiency
- ➢ Load factor

- Operational efficiency

9. What are available energy sources for various power plants?

- Conventional energy sources or Non-renewable energy sources
- Non conventional energy sources or Renewable energy sources

10. What are the major power limitations of conventional energy sources?

- Resources for power generation i.e, coal, gas etc., are limited
- The hydro power is seasonal and varies depending upon the rainfall in the catchment areas.
- Submersion of land area due to raise in water level
- Centralized power generation and distribution of the same to long distances will result in high losses.
- The energy conversion process from thermal power projects results in emission of green house gases.

10. List out the various conventional and non conventional power plant:

Types of conventional power plant:

1. Hydro power plant
2. Steam power plant
3. Nuclear power plant
4. Gas turbine power plant

Types of non-conventional power plant:

1. Tidal power plant
2. Wind power plant
3. Geothermal power plant
4. Solar power plant
5. Wave power plant
6. MHD Generation

12. What is hydraulic/ Pneumatic type ash handling system?

- The hydraulic system carried the ash with the flow of water high velocity through a channel and finally dumps into a sump. The hydraulic system is divided into a low velocity and high velocity system.
- The advantages of this system are that its clean, large ash handling capacity, considerable distance can be traversed, absence of working parts in contact with ash
- In pneumatic type ash handling is the most popular method used in medium level power plants. It uses dense phase conveying system for conveying ash is totally enclosed without any leakage. The system can convey materials up to distance of around 200 -250 mts.

13. List the challenges of ash handling:

- Indian coal contains high ash content generally which tends to be inconsistent.
- Design of the system has to adequately cover anticipated variations and be capable of handling the worst scenario.
- System has to be environmentally friendly.
- System has to be energy efficient

14. Comment on thermal efficiency of a steam power plant.(Dec 2012) (NOV/DEC 2017)

- Due to practical limitations in heat transfer, all the heat produced by combustion is not transferred to the water; some is lost to the atmosphere as hot gases.
- The coal contains moisture. Also coal contains a small percent of Hydrogen, which

also gets converted to moisture during combustion.

- ❖ In the furnace, moisture vaporizes taking Latent heat from the combustion heat and exits the boiler along with the hot gases.
- ❖ Improper combustion of coal, hot ash discharged from the boiler and radiation are some of the other loses

15. What are all the types of Mechanical drafts?

There are three types of mechanical drafts: They are:

- ❖ Induced draft
- ❖ Forced draft
- ❖ Balanced draft

16.What is Deaeration?

❖ Mechanical and chemical deaeration is an integral part of modern boiler water protection and control. Deaeration coupled with other aspects of external treatment, provides the best and highest quality feed water for boiler use.

17. What is the Function of deaeration? (May/June 2012)

The purpose of deaeration is:

- ❖ To remove oxygen, carbon dioxide and other non condensable gases from feed water.
- ❖ To heat the incoming makeup water and return condensate to an Optimum temperature
- ❖ Minimizing solubility of undesirable gases.
- ❖ Providing the highest temperature water for injection to the boiler.

18. What are the types of deaerators?

- ❖ Tary-Type Deaerating heaters .
- ❖ Spray-Type Deaerating heaters

19. What is meant by cooling Towers?

❖ It is a tower or building like device in which atmospheric air circulates in direct or indirect contact with warmer water and water is thereby cooled. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid.

20. List the types of cooling towers:

1.Evaporative or wet cooling tower

2.Nonevaporative or dry cooling tower

(a) Air cooled condensers

(b)Air cooled exchangers

21. List the types of cooling functions to condense the steam:

- ❖ Once-through wet cooling
- ❖ Recirculating wet cooling
- ❖ Dry cooling

22. List the factors to be considered while choosing a site for steam power station:

- ❖ Supply of fuel
- ❖ Availability of water
- ❖ Transportation facilities
- ❖ Cost and type of land
- ❖ Nearness to load centres
- ❖ Distance from populated area

23. List the thermal power plant in Tamilnadu.

- ❖ Alathiur(2*18MW), Tamilnadu, Madras cements
- ❖ Ennore(2*60MW,3*110MW) Tamilnadu Electricity Boar
- ❖ Neyveli(6*50MW,2*100MW) TamilnaduNeyveli lignite corp Ltd.

24. Define super heater: (Nov/Dec 2012) or What is the function of super heaters in a thermal plant?(may/june 15)

❖ A Super heater is a device used to convert saturated steam into a dry steam used for power generation or processes steam which has been super heated is known as superheated steam.

25. List the types of super heaters:

1. Radiant super heater- absorb heat by radiation
2. Convention super heater-absorb heat via a fluid
3. Separately fixed super heaters- it is totally separated from the boiler

26. Name the four major circuits in steam power plant.

1. Coal and ash circuit
2. Air and flue gas circuit
3. Feed water and steam circuit
4. Cooling water circuit

27. What consists of air and flue gas circuit?

❖ Air and flue gas circuit consists of forced draught fan, air pre-heater, boiler, furnace, super heater, economizer, dust collector, induced draught fan and chimney.

28.What are functions of a draught system? (May 2012)(may/june 16)

The functions of draught is

1. To supply the required quantity of air to the furnace
2. To remove the burnt gases from the furnace.

29. How the combustion rate of the system increased?

Combustion rate is increased

- ❖ Thermal efficiency is increased
- ❖ Fuel feed rate is increased

30.How the combustion equipment for burning coal is classified? (May 2012)

Combustion equipment for burning coal is classified based on the following:

(*i*) Type of furnace

(*ii*) Method of coal firing such as:

(*a*) Hand firing

(*b*) Stoker firing

(*c*) Pulverized fuel firing.

(*iii*) Method of air supply to the furnace. It is necessary to provide adequate quantity of secondary air with sufficient turbulence.

(iv) Type of burners used.

(*v*) Mixing arrangement of fuel and air

31.What is the function of cooling tower?

❖ Cooling tower is used to control the temperature of water required for the plant. It reduces the water consumption of the plant.

32.What are the different types of draught system? (Nov 2011)

a) Forced draught
b) Induced draught
c) Natural draught

33.Mention the uses of fly ash. (May 2010)

- Fly ash improves the concrete performance to make it strong, more durable, and more resistant to chemical attack. Fly ash also provides some good benefits for our environment.

34. What are the methods used for handling of coal?

- By sea or Transportation
- Byriver Transportation
- By rail Transportation
- By rope ways Transportation by road

35.What are the types of miles used for pulverizing the coal?

- **B**all mill
- Ball and race mill Impact or hammer **mill** Bowl mill

36. What are the types of pulverized fuel system?

- Unit system
- Central system

37. What are the all the types of pulverized fuel burners?

- U- flame burner
- Turbulent burner
- Tangential burner
- Cyclone burner

38. What are the types of coal?

- Peat
- Lignite
- Bituminous coal
- Anthracite coal

39. What are the steps involved in plant handling of coal?

- Preparation
- Transportation
- Storage
- Weighing

40. What are the modern methods used in ash handling system? (APRIL/MAY 2010)

- Mechanical handling
- Hydraulic system
- Pneumatic system
- Steam jet system

41. What is cyclone separator?

- Cyclone separator is a dust cleaning device it is used remove the dust from the fly ash. The cyclone separator produces the whirling motion of the gas within the chamber and throws

the heavy dust particles to the sides and fallout in the colour.

42. What is the mechanism of pulverised firing system? (Dec 08)

❖ In this, the coal reduced to a fine powder with the help of grinding mill and the projected into the combustion chamber with the help of hot air. The amount of secondary air to complete the combustion is supplied separately.

43. What are the different types of cooling tower? (Dec 09)

- ❖ Natural draft sprays filled tower
- ❖ Natural draft pached type tower
- ❖ Hyperbolic cooling tower
- ❖ Induced draft tower

44. What is pulverization?

- ❖ It is the method of mining the coal in the form of powder Pulverization is done by various types of pulverising mills.

45. What is dry cooling tower?

- ❖ It offers a solution to the problem of thermal pollution of water. The dry cooling system rejects the heat directly to the atmosphere.

46. What are the limitations of chimney draught?

- ❖ The maximum pressure available is 10 to 20mm of water under normal atmosphere and flue gas temperature
- ❖ The flue discharged to at high temperature resulting loss in efficiency of the plant

47. What is the function types of water distribution system used in cooling tower?

- ❖ Gravity flow
- ❖ Spray nozzle
- ❖ Rotating distribution system

48. What are the different impurities in feed water?

- ❖ Un dissolved and suspended solids
- ❖ Dissolved salts and minerals
- ❖ Dissolved solids

49. Write the use of water level indicator in a boiler? (Nov/Dec 2013)

❖ Water level indicator is used to measure water levels in standpipes. Its main function is to indicate the level of water in the boiler constantly.

❖ Every boiler is normally fitted with two water level indicators.

50. What is cooling tower approach?

❖ The temperature difference between WBT of incoming air and outgoing temperature of water is known as cooling tower approach

51.Why thermal power plant is not suitable for supplying fluctuating loads?

❖ Due to the energy output fluctuations, wind power plants cause problems regarding energy transfer, reduced availability for meteorological reasons and the resulting required "Hour reserve from conventional thermal power plants".

52.What are the types of oil burners?

- ❖ Steam (or) air atomizer oil burner

❖ Pressure atomizer with tangential oil feed

53.What is function of hot primary air?(Nov/Dec 2013)

❖ The purpose of the air pre heater(hot primary air) is to recover the heat from the boiler flue gas which increases the thermal efficiency of the boiler by reducing the useful heat lost in the flue gas.

54. State the characteristics of good ash handling plant.(May 2011)

❖ Ash handling plant removes of rock originating from mine roof, removes of ash forming and sulphur bearing minerals, dries to remove excessive surface moisture and blends the different coals to achieve desired physical and chemical properties.

55. What do you understand by the term boiler draught? (May 13) (Nov/Dec 2016)

❖ Draught is defined as the moment of air through full bed and produces a flow of hot gases to the boiler and chimney requires are pressure difference between gas pressure and atm. Pressure.

56. Define fluidized bed combustion? (Nov/Dec 2010)

❖ When the high velocity gas is passed through a packed bed of finely divided solid particles, the particles become suspended in the gas stream and the packed bed becomes a fluidized bed.

❖ When the gas velocity is very high, the fluidized bed become turbulent and rapid mixing of particles occurs.

❖ Ultimately, the, behavior of mixture solid particles and gas become a fluid. Burning of a fuel in such a state is known as Fluidized Bed Combustion. The boiler plant using this fluidized bed combustion is known as fluidized bed boilers.

57.What are the accessories and mountings used in a boiler? (May 13)

The different boiler mountings are

- Water gauge (or) water level indicator
- Pressure gauge (or) steam gauge
- Safety valves
- Fusible plug
- Stop valve
- Blow off cock
- Feed check valve

The different boiler accessories are

1. Economizer
2. Air Pre-heater
3. Soot Blowers
4. Condenser
5. Cooling Tower
6. Super heater
7. Reheater

58.What is the necessity of feed pump in a thermal power plant?

❖ The feed pump is required to force the water in to the boiler which is under pressure.

❖ Safe operating of boilers requires highly dependable functioning of feed water equipment and standby feed pumps are installed for this purpose.

59.DefinepH.Why high pH value is preferred to prevent the corrosion?(May/June 15)

❖ pH is a measure of the hydrogen ion concentration of a solution.

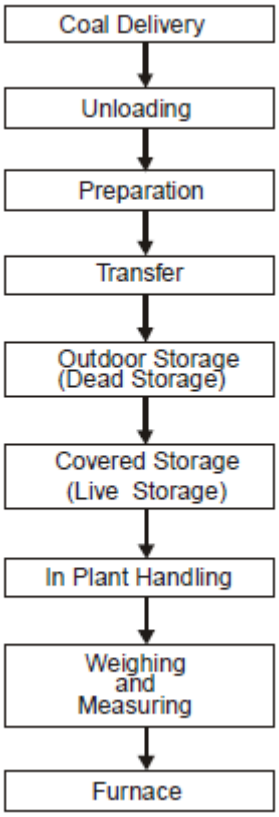
- Solutions with a high concentration of hydrogen ions have a low pH and solutions with low concentrations of H+ ions have a high pH
- A higher pH means there are fewer free hydrogen ions, so it is preferred to prevent the corrosion

60.What are the methods of controlling fan? What are the disadvantages of FD fans?(Nov/dec14)

Methods of controlling fan:
(i)Voltage Regulation
(ii)Programmable
(iii)Thermal Speed Control
(iv)External Controllers

- The drawbacks of FD fans are: leakage and uniform distribution problem of air due to high velocity from the fan.In the induced draft cooling towers moist air is discharged higher in the atmosphere thereby dispersing to a greater distance from the tower.

61.Describe the steps involved in the inplant handling of coal?(may/june 14)



62.What is the different pollution in the flue gas?

- Oxides of nitrogen
- Oxides of sulphur
- Carbon monoxide
- Particulates

63.What are the methods used for reduction of SO_2 pollutant?

- Adding lime stone ($caco_3$) to the coal
- Using wet scrubbers
- Using electro static precipitator

64.What are the methods used for controlling the NO_X

- Reduction of temperature in combustion zone

- ❖ Reduction of residence time in combustion zone
- ❖ Increase in equivalence ratio in the combustion zone

65.What is acid rain?

- ❖ The CO_2, SO_2 and NOx contact the water during rainy season. So H_2SO_4 and HNO3 acids are formed and mixed with water during the rainfall.

66.What are the equipments used to control the particulates?

- ❖ Scrubbers
- ❖ Cyclone separators
- ❖ Fabric filter
- ❖ Electro static precipitator

67. State the characteristics of good ash handling plant.(May 2011)

❖ Ash handling plant removes of rock originating from mine roof, removes of ash forming and sulphur bearing minerals, dries to remove excessive surface moisture and blends the different coals to achieve desired physical and chemical properties.

68. What do you understand by the term boiler draught? (May 13)

❖ Draught is defined as the moment of air through full bed and produces a flow of hot gases to the boiler and chimney requires are pressuredifference between gas pressure and atmospheric presuure.

69. What is heat rate? Nov-Dec 2016

❖ The economy or efficiency of a steam power plant cycle is expressed in terms of heat rate, which is total thermal input to the cycle divided by the electrical output of the units.

70. What is Steam Rate?Nov-Dec 2016

❖ The actual steam rate of a turbine can be determined by dividing the actual throttle steam flow rate by the actual corresponding kilowatts, at the generator terminals, produced by that amount of steam. The actual steam rate can also be determined by dividing the theoretical steam rate by the engine efficiency of the turbine generator.

71. What is meant by supercritical boiler?(Nov/Dec 15)(Apr/May 2018)

❖ **A supercritical steam generator**is a type of **boiler** that operates at **supercritical** pressure, frequently used in the production of electric power.

72. What is pulveriser and why it is used?(Nov/dec 15)

❖ A pulverizer or grinder is a mechanical device for the grinding of many different types of materials.for example pulveriser mill is used to pulverize coal for combusion in the steam – generating furnace of fossil fuel power plant.

73. What are once through boilers?(may/june 16)

- ❖ The boiler in which water flows, without recirculation ,sequentially through the economizer ,furnance wall and evaporating and superheating tubes are called as once through boilers**.**

74. Define compounding of steam turbines?[Apr/May 2017]

Compounding of steam turbines is the method in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine.

75. What is stroker? Classify it? [Apr/May 2017]

A mechanical stoker is a mechanical system that feeds solid fuel like coal, coke or anthracite into the furnace of a steam boiler.Types: over feed, cross feed, under feed.

76. Reason out why cogeneration is quite viable in sugar industries compared to that in other industries? (NOV/DEC 2017)

❖ In **cogeneration plant** the low pressure steam coming from turbine is not condense to form water, instead of it its used for heating or cooling in building and factories, as this low pressure steam from turbine has high thermal energy.

❖ The **cogeneration plant** has high efficiency of around 80 - 90 %. In India, the potential of power generation from cogeneration plant is more than 20,000 MW.

77. What are Binary Cycle? (APR/MAY 2018)

Binary Vapour Cycle

❖ No single fluid can meet all the requirements of vapour power cycle.Normally water is good working fluid of vapour power cycle.But in high temperature range,there are few better fluid available,such as diphonyl ether,aluminium bromide and mercury.

❖ Among these,fluids,mercury is widely used as working fluid because it does not decompose gradually at high temperature.

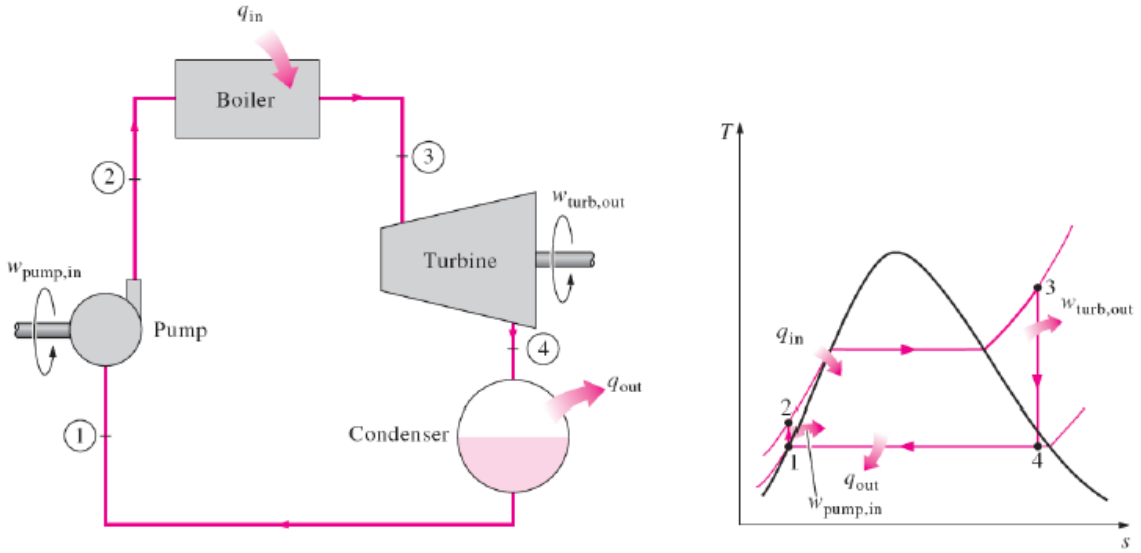
PART B

1. Explain layout of thermal (or) Steam power plant. (Dec 2010,11,May 10,11) (or) Draw the Rankin cycle for a coal fired and steam thermal power plant, State the means of increasing the efficiency of the plant.(DEC 2012) or Draw the layout of modern steam power plant and explain its working principle?(May/June 14) or Explain with neat sketch of thermal electric power plant station and discuss the fuction of major components in it.(Nov/dec 15) (Nov/Dec 2016).

Principle

- The chemical energy of the fuel is converted into heat energy in the boiler which is converted into mechanical energy by the steam turbine.
- Mechanical energy is used for generating power with the help of generator.
- The steam turbine works based on Rankine cycle.

Rankine Cycle:



Rankine Cycle

- Steam is generated in a boiler, expanded in the prime mover and condensed in the condenser and fed into the boiler again.

1-2	Isentropic compression in a pump
2-3	Constant pressure heat addition in a boiler
3-4	Isentropic expansion in a turbine
4-1	Constant pressure heat rejection in a condenser

Steam power plant

- The heat energy is converted into mechanical energy by the steam turbine and that mechanical energy is used for generating power with the help of generator.

A steam power plant must have following equipment:

(a) A furnace to burn the fuel.
(b) Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water into steam.
(c) Main power unit such as an engine or turbine to use the heat energy of Steam and perform work.
(d) Piping system to convey steam and water.

❖ In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.

The layout of the steam power plant :.

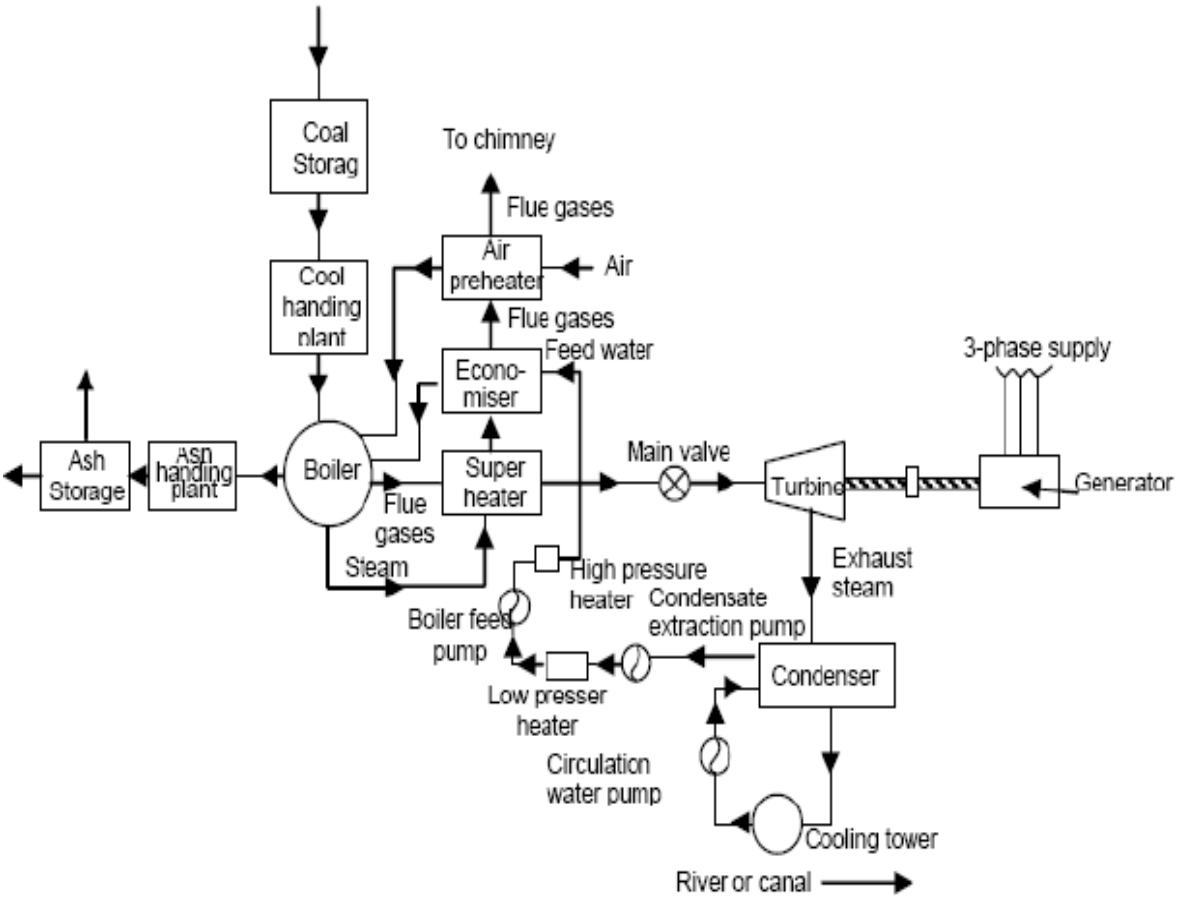


Fig . Shows a schematic arrangement of a steam power station

Four main circuits of steam power plant:.

1.coal and ash circuit
2.Air and flue gas circuit
3.Water and steam circuit
4.Cooling water circuit

Characteristics of steam power plant:

1.Low cost compared with hydro power plant
2.Reduced water requirement
3.Higher reliability and availability

❖ A steam power plant using steam as working substance works basically on Rankine cycle. Steam is generated in a boiler, expanded in the prime mover and condensed in the condenser and fed into the boiler again.

The different types of systems and components used in steam power plant are as follows:

(a) High pressure boiler
(b) Prime mover
(c) Condensers and cooling towers
(d) Coal handling system
(e) Ash and dust handling system
(f) Draught system
(g) Feed water purification plant

(h) Pumping system
(i) Air pre heater, economizer, super heater, feed heaters.

Coal and ash circuit:

- In this circuit, the coal from the storage is fed to the boiler through coal handling equipment for the generation of steam.
- Ash produced due to the combination of coal is removed to ash storage through ash handling system.
- Indian coal normally contains 30 to 40% of ash and hence sufficient space is necessary nearer to the power plant for ash disposal.

Air and flue gas circuit:

- Air is supplied to the combustion chamber of the boiler either through F.D. or I.D. fan or by using both.
- The dust from the air is removed before supplying to the combustion chamber through air filter and passes through air pre heater where air is preheated by using the waste heat from the flue gases flowing through the chimney.
- After burning is completed, the heat is transferred to the boiler feed water through the hot gases to generate steam.
- The flue gases are then exhausted to the atmosphere through economizer, air pre heater to recover the waste heat and then to dust collector to remove the dust from it before passing through chimney.

Feed water and steam flow circuit:

- This circuit consists of boiler feed pump. Boiler, turbine, feed heaters and feed pumps.
- The steam generated in the boiler is fed to the steam turbine to develop the power. After expansion, the low pressure steam is condensed in the condenser.
- The condensate leaving the condenser is first heated in low pressure heater and then in high pressure heater by using the steam tapped from various extraction points of the turbine.
- This hot water is then supplied back to the boiler through economizer where the hot water is further heated by flue gases.

Cooling water circuit:

- This circuit consists of circulating water pumps, condenser, cooling water pumps and cooling tower.
- Water circulating through the condenser may be takes from various sources such as river, lake or sea.
- The cooling water is taken from upper side of the river and heated water is discharged to the lower side of the river. Such system is called open system. Which is possible if adequate water is available throughout the air?
- If the adequate water is hot available, then water coming out from the condenser is coded either in cooling pond or cooling tower. This is closed system. But open system is more economical than closed one.

Operation of steam power plant:

- Coal received in coal storage yard of power station is transferred in the furnace by coal handling unit. Heat produced due to burning of coal is utilized in converting water contained in boiler drum into steam at suitable pressure and temperature.
- The steam generated is passed through the super heater. Superheated steam then flows through the turbine. After doing work in the turbine the pressure of steam is reduced.
- Steam leaving the turbine passes through the condenser which is maintained the low pressure of steam at the exhaust of turbine.
- Steam pressure in the condenser depends upon flow rate and temperature of cooling water and on effectiveness of air removal equipment.
- Water circulating through the condenser may be taken from the various sources such as river, lake or sea.

- If sufficient quantity of water is not available the hot water coming out of the condenser may be cooled in cooling towers and circulated again through the condenser.
- Bled steam taken from the turbine at suitable extraction points is sent to low pressure and high pressure water heaters.
- Air taken from the atmosphere is first passed through the air pre-heater, where it is heated by flue gases. The hot air then passes through the furnace.
- The flue gases after passing over boiler and superheater tubes, flow through the dust collector and then through economiser, air pre-heaterand finally they are exhausted to the atmosphere through the chimney.

Site selection for thermal plant:

1. Availability for coal
2. Ash disposal facilities
3. Nature of land
4. Availability of water
5. Transport facilities
6. Other factors (availability of labours, public problems, size of the plants)

Advantages:

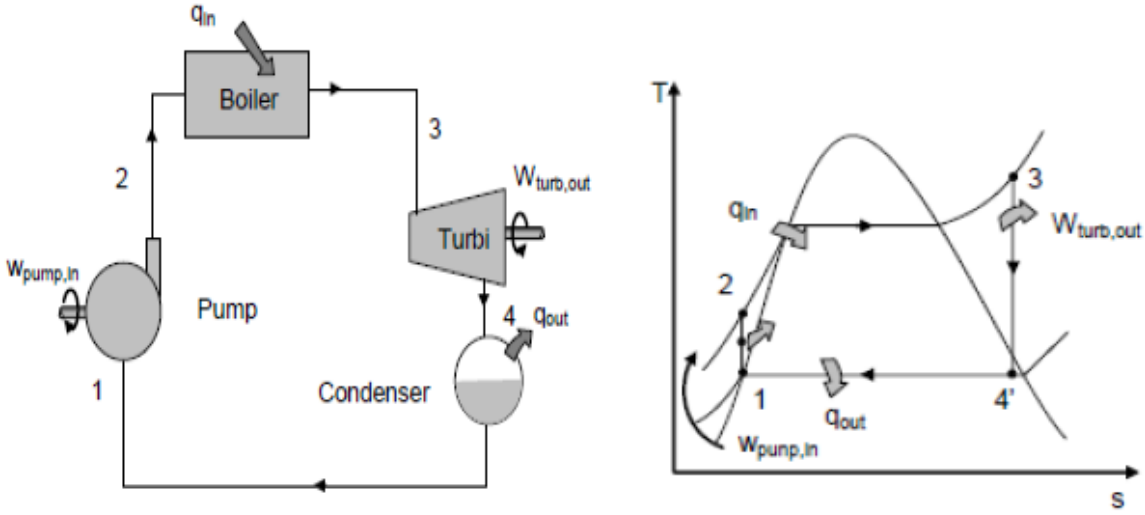
1. Power production does not depends on nature of mercy
2. Initial investment is low
3. The time requirement for construction and commissioning of thermal power plant require less period of time

Drawbacks:

1. As compared to hydro power plant, life and efficiency are less
2. Transportation of fuel is a major problem in this type of power plant
3. It cannot be used as a peak load power plant
4. The coal (fuel) needed may be exhausted by gradual use.

2. What are all the methods to improve thermal efficiency of a Rankine cycle? (NOV/DEC 2017)

- The Rankine cycle is an ideal cycle which is used for comparing the performance of steam power plants.



Process 1 -2: Isentropic compression in pump (compressors)

- The water is heated at constant volume process from and pressure is also . From . During this process heat is added for heating.

Process 2 – 3: Constant pressure heat addition in boiler

- In this process water is converted into steam isothermally and is basically (i.e) T = constant and P = constant.

- At point 2, the working fluid is existing as a water and point 3 the working fluid converted into steam.

Process 3 – 4: Isentropic expansion in turbine

- The dry saturated steam expands isentropically in the turbine for developing mechanical work.
- Pressure falls from and temperature Therefore it is converted into dry steam to wet steam.

Process 4 -1: Constant pressure heat rejection in a condenser

- The wet steam is then condensed in a condenser isothermally and is basically. Then wet steam is converted to water in condenser.
- This process is a heat rejection process; heat is rejected from wet steam to atmosphere.

Energy Analysis of the Rankine Cycle

- All four components associated with the Rankine cycle (the pump, boiler, turbine and condenser) are steady-flow devices, and thus all four processes that make up the Rankine cycle can be analyzed as steady-flow process.

How can We Increase the Efficiency of the Rankine cycle?

The three ways by which efficiency of the Rankine cycle can be increased are :

(a) Lowering the condenser pressure (Lowers *T*low, *av*).
(b) Superheating the steam to high temperatures (Increases *T*high, *av*).
(c) Increasing the boiler pressure (Increases *T*high, *av*).

In addition to that the efficiency is increased by

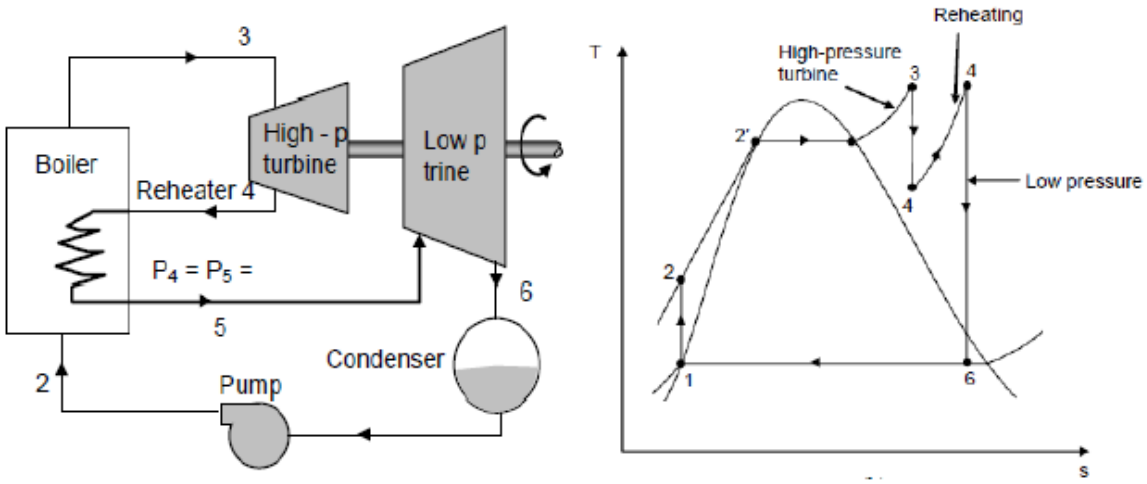
1. By reheating steam in between two operating pressure.

2. By adopting regeneration of steam.

3. By using both reheat and regeneration.

1. Reheat cycle

The schematic and T-*s* diagram of the Reheat cycle is shown in Figure below



From the figure ,the efficiency of the reheat cycle

$$\eta\text{reheat} = \frac{\text{workdone}}{\text{heat supplied}} = \frac{w}{Q_S}$$

$$\text{where, } Q_s = (h_1 - h_6) + (h_3 - h_2)$$

$$w = (h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)$$

Where, $h_1 - h_2$ = first steam turbine work

$h_3 - h_4$ =second steam turbine work

$h_6 - h_5$ = pump work

$$\eta reheat = \frac{(h_1 - h_2) + (h_3 - h_4) - (h_6 - h_5)}{(h_1 - h_6) + (h_3 - h_2)}$$

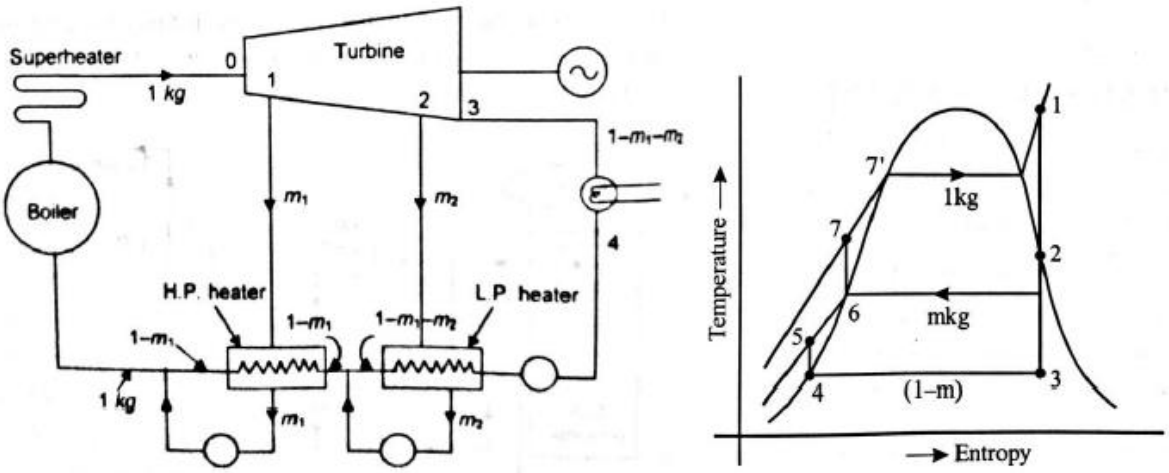
Neglecting pump work,

$$\eta reheat = \frac{(h_1 - h_2) + (h_3 - h_4)}{(h_1 - h_6) + (h_3 - h_2)}$$

where, $h_6 = h_5$

2. Regenerative cycle:

- Another way of increasing the thermal efficiency of the Rankine cycle is by regeneration.
- During a regeneration process, liquid water (feed water) leaving the pump is heated by steam bled off the turbine at some intermediate pressure in devices called feed water heaters.
- Feed water heater in which heat is transferred from the extracted steam to the feed water without any mixing taking place. The two streams now can be at different pressure, since they do not mix.



Heat supplied externally in the cycle = $(h_0 - h_{f6})$

Isentropic work done,= $(h_1 - h_1) + (1 - m_1)(h_1 - h_2) + (1 - m_1 - m_2)(h_2 - h_3)$

Thermal efficiency, = $\frac{\text{workdone}}{\text{Heat supplied}}$

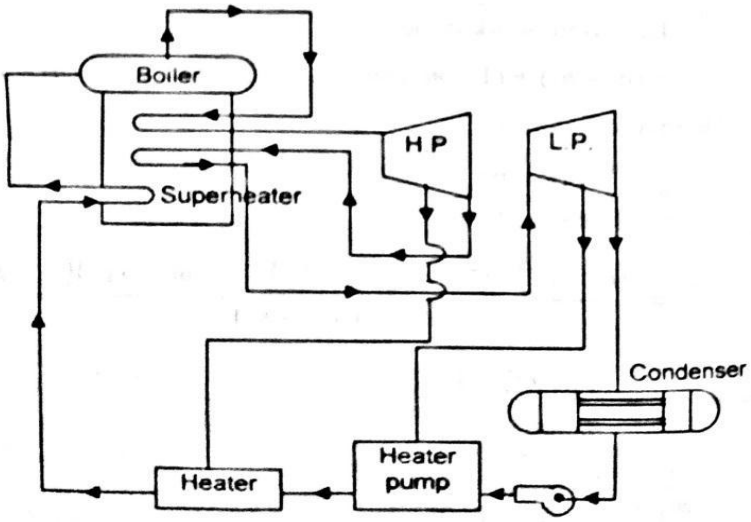
$$= \frac{(h_1 - h_1) + (1 - m_1)(h_1 - h_2) + (1 - m_1 - m_2)(h_2 - h_3)}{(h_0 - h_{f6})}$$

Where, $m_1 = \frac{h_{f6} - h_{f5}}{h_1 - h_{f5}}$

$$m_2 = \frac{(1 - m_1)(h_{f5} - h_{f3})}{(h_2 - h_{f3})}$$

3. Reheat-Regenerative Cycle:

- Reheat-regenerative cycle is used in actual thermal power plant with high steam pressure to increase the overall efficiency of the cycle which is higher than only reheat or only regenerative cycle



3. With a neat sketch briefly explain about fluidized bed combustion. (Dec 2011)(May/June2012) or what is fluidized bed combustion system? Sketch and describe Fluidized bed combustion (FBC) system? (May/June 14) or Explain the working and advantages of a fluidized bed combustion system? (Apr/May 16)(NOV/DEC 2017)(APR/MAY 2018)

Fluidized bed combustion (FBC) system:

- When a packed bed of finely divided inert, refectory sand like solid particles over a perforated plate is subjected to a evenly distributed upward flow of air.
- In higher air velocities, the gravitational force of particles is balanced by the frictional forces between the fluid (air) and particles. This causes the particles to become suspended in the air steam.

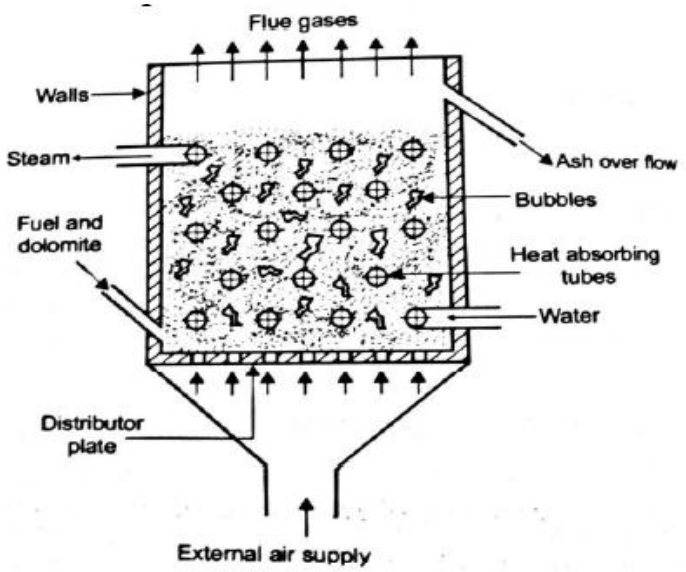


Fig 5.1 Fluidized bed combustion (FBC) system

- This vigorous mixing of particles results the bed at highly turbulent. This bed is called fluidized bed and burning the full in such a state is known as fluidized bed combustion (FBC).
- The air velocity is maintained at a rate that overcomes the gravitational focus on the particles without carrying them out of furnace.

Classification of FBC:

They are classified into two types

1. Atmospheric fluidized bed combustor (AFBC)
2. Pressurized fluidized bed combustor (PFBC)

❖ In AFBC system, the pressure inside the bed is maintained at atmospheric level. This system uses both forced and induced draft fan due to this bed pressure.

❖ In PFBC, the bed is operated under pressure by supplying the compressed air at pressure of up to 10 bar, which results in slightly higher heat – transfer rates.

❖ This combustion is pressurized environment results in a compact furnace and proved combustion efficiency.

Atmospheric Fluidized bed combustion:

❖ In atmospheric fluidized bed combustion system, the pressure inside the bed is maintained at atmospheric level and this system utilizes both forced and induced draft fan.

AFBC system classified into

1. Bubbling fluidized bed boiler
2. Circulating fluidized bed boiler

Atmospheric bubbling fluidized bed boiler:

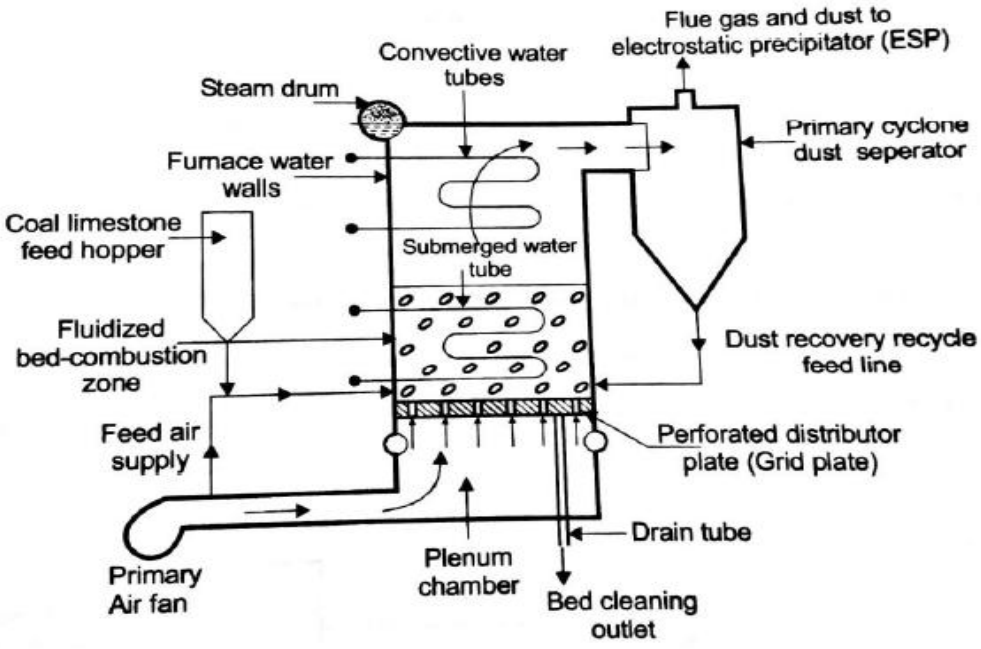


Fig 3.2 Atmospheric bubbling fluidized bed boiler

❖ Water tubes are located horizontally in fluidized bed combustion zone and upper part of the combustion chamber.

❖ Steam drum has water in lower half and steam is upper half, super heater tubes are also located in the combustion zones of the furnace which is made of boiler plate forming under walls.

❖ Crushed coal (6 – 20 mm) is injected into the fluidized bed of limestone just above an air – distribution grid at the bottom of the bed.

❖ Hot air from the air plenum flaw upwards into the bed through the grid, the bed particles agitates at high speed shrilling action and the bed now become furnace.

❖ This rains the temperature of the particle in the combustion zone and the sliding mixture starts burning.

❖ The products of combustion leaving the bed carriers a large proportional of unburned carbon particles which can be separated by passing through the cyclone separator. This can be recycled back to combustion zone.

Atmospheric circulating fluidized bed boiler:

The circulating fluidized bed boilers are designed with following modifications.

1. Providing sloping distributor plate to give an air slide effect.
2. Providing non-uniform fluidizing velocities over the bed.
3. Bending one of the PBC walls over the bed to certain the light particles.

❖ In this system air at different velocities is supplied at different points along the surface of the bed and thus the bed become stable.

❖ At this stable condition, the bed remains in fluidized condition and so all the lightmaterials get burned is that condition. The burning is efficient because of high turbulence.

❖ The heavy particles accumulated along with ash produced due to combustion.

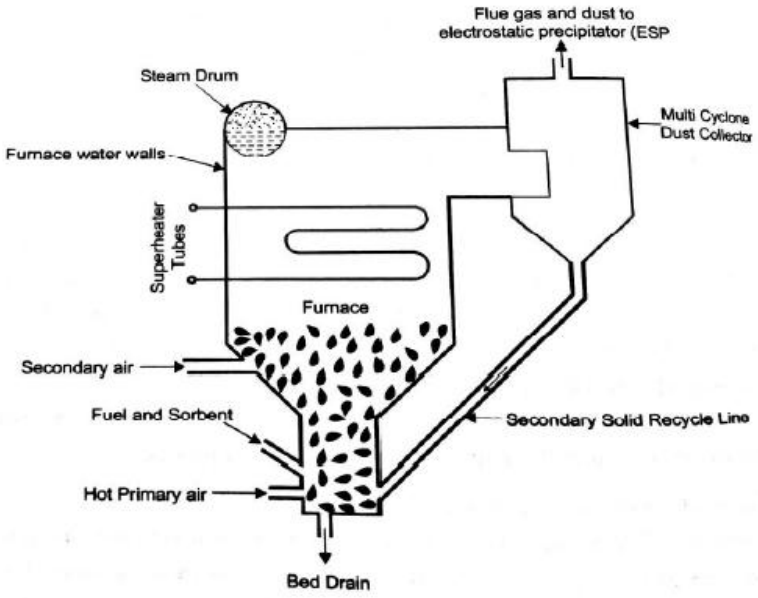


Fig3.3 Atmospheric circulating fluidized bed boiler

Pressurized fluidized bed combustor:

This combustor will be of two types

1. Pressurized bubbling fluidized bed combustor (PBFBC)
2. Pressurized circulating fluidized bed combustor (PCFBC)

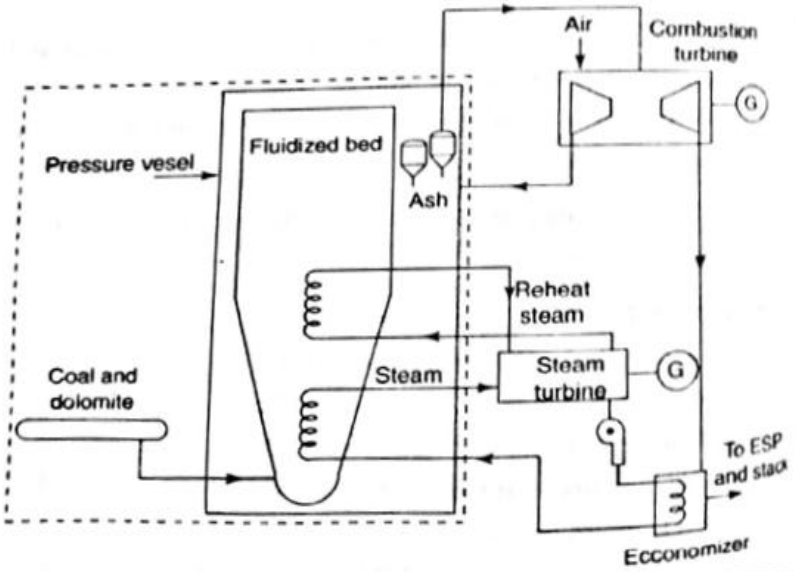


Fig 3.4 Pressurized bubbling fluidized bed combustor (PBFBC)

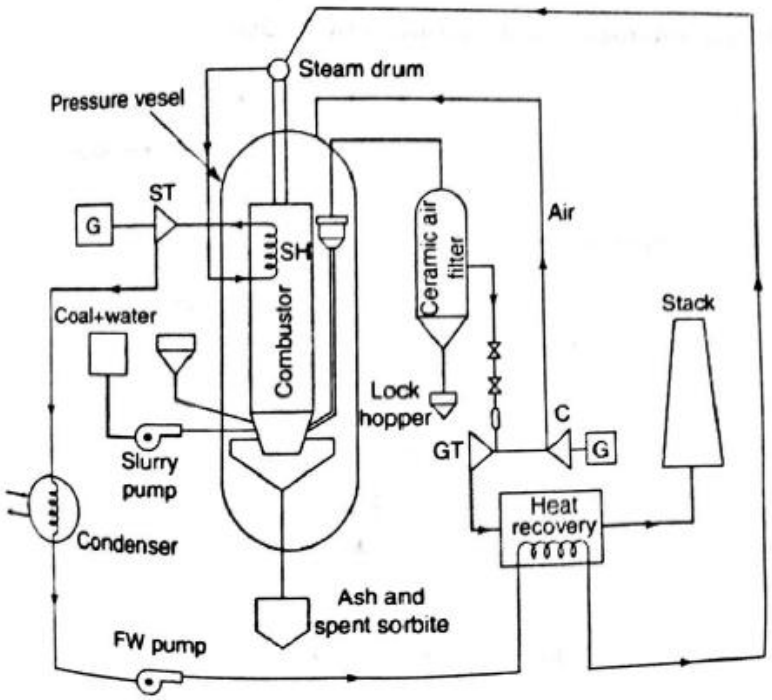


Fig 3.5 Pressurized circulating fluidized bed combustor (PCFBC)

❖ PBFBC, the solid particles are fluidized in bubbling fluidized mode by maintaining the superficial gas velocity to in between the minimum bubbling velocity of coarser particles and terminal velocity of finer particles.

❖ Coal fed together with limestone is burnt by supplying compressed air. Heat so generated in fluidized bed is extracted by water carrying tubes immersed in bed.

❖ The hot clear gas from cyclone separator is given to gas turbine to generate electricity.

❖ The steam produced in the combustor or the waste heat recovery heat exchanger at the gas turbine exit produces further power by expanding through steam turbine.

4.What is meant by high pressure boilers? Explain briefly about their types. Explain with a neat sketch the function of Bension Boiler and Give its advantages and disadvantages.(May/June 2013) or Briefly discuss the Loeffler boiler and enumerate its advantages.(may/june 15),(Nov-Dec 2016) (NOV/DEC 2017)

❖ In all modern power plants, high pressure boilers (> 100 bar) are universally used as they offer the following advantages.

❖ In order to obtain efficient operation and high capacity, forced circulation of water through boiler tubes is found helpful.

❖ Some special types of boilers operating at super critical pressures and using forced circulationsare described in this chapter.

1. The efficiency and the capacity of the plant can be increased as reduced quantity of steam is required for the same power generation if high pressure steam is used.

2. The forced circulation of water through boiler tubes provides freedom in the arrangement of furnace and water walls, in addition to the reduction in the heat exchange area.

3. The tendency of scale formation is reduced due to high velocity of water.

4. The danger of overheating is reduced as all the parts are uniformly heated.

5. The differential expansion is reduced due to uniform temperature and this reduces the possibility of gas and air leakages.

Supercritical boilers:

❖ Boilers are usually designed foe high working pressures for steam generating plants.Large number of steam generating plants are designed to work between the range of 125 atm and 510°C to 300 atm and 660°C.

❖ These types of steam generator are basically categorised into sub critical and super critical boilers.

❖ Once through boilers are the only type suited to supercritical operation because the latent heat of vaporisation at and above the critical pressure is zero.

❖ Moreover supercritical boilers require only economiser and superheater .It is a common practice that supercritical boilers are employed when the capacity of the plant is above 300MW.

Advantage of Supercritical boilers:

1.Heat transfer rate is high.
2.It is possible to maintain more stable pressure level.
3.The problem of erosion and corrosion are minimised due to absence of two phase mixture.
4.It is possible to achieve higher thermal efficiency(about 40 to 42%)
5.It can be used to generate peak load by changing the operating pressure

LAMONT BOILER

❖ A forced circulation boiler was first introduced in 1925 by La Mont. The arrangement of water circulation and different components are shown in Fig.4.1

❖ The feed water from hot well is supplied to a storage and separating drum (boiler) through the economizer. Most of the sensible heat is supplied to the feed water passing through the economizer. A pump circulates the water at a rate 8 to 10 times the mass of steam evaporated.

❖ This water is circulated through the evaporator tubes and the part of the vapour is separated in the separator drum.

❖ The large quantity of water circulated (10 times that of evaporation) prevents the tubes from being overheated.

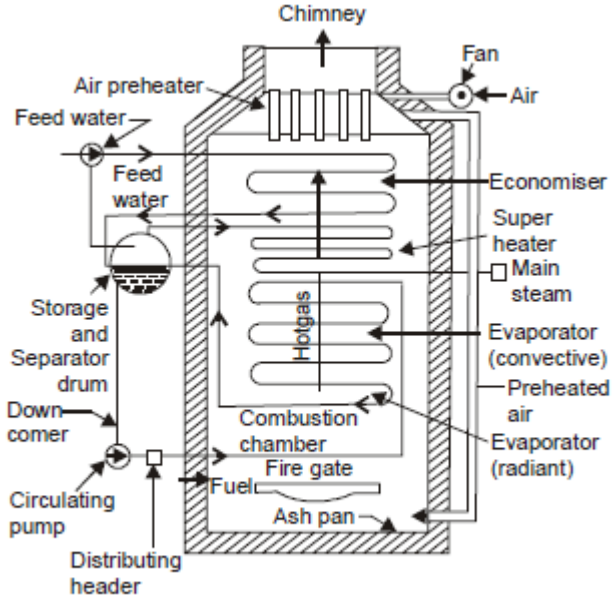


Fig. 5.5. La Mont Boiler.

❖ The centrifugal pump delivers the water to the headers at a pressure of 2.5 bar above the drum pressure.

❖ The distribution headers distribute the water through the nozzle into the evaporator.

❖ The steam separated in the boiler is further passed through the super-heater.

❖ Secure a uniform flow of feed water through each of the parallel boiler circuits a choke is fitted entrance to each circuit.

❖ These boilers have been built to generate 45 to 50 tonnes of superheated steam at a pressure of 120 bar and temperature of 500°C. Recently forced circulation has been introduced

in large capacity power .

LOEFFLER BOILER

❖ The major difficulty experienced La Mont boiler is the deposit ion of self and sediment on the inner surface of the wither tubes the deposition reduced the heat transfer and ultimately the generating capacity.

❖ The further increased the danger of over heaving the tubes due it salt deposition as it has high thermal deposition resistance.

❖ This difficulty was solved in Lo filler boiler by the differing the flow of water in to the boiler tubes.

❖ Most of the stream is generated outside from the federated using the superheated steam coming out from the boiler .the arrangement of the different components ,and the water and steam circulation are shown in fig.

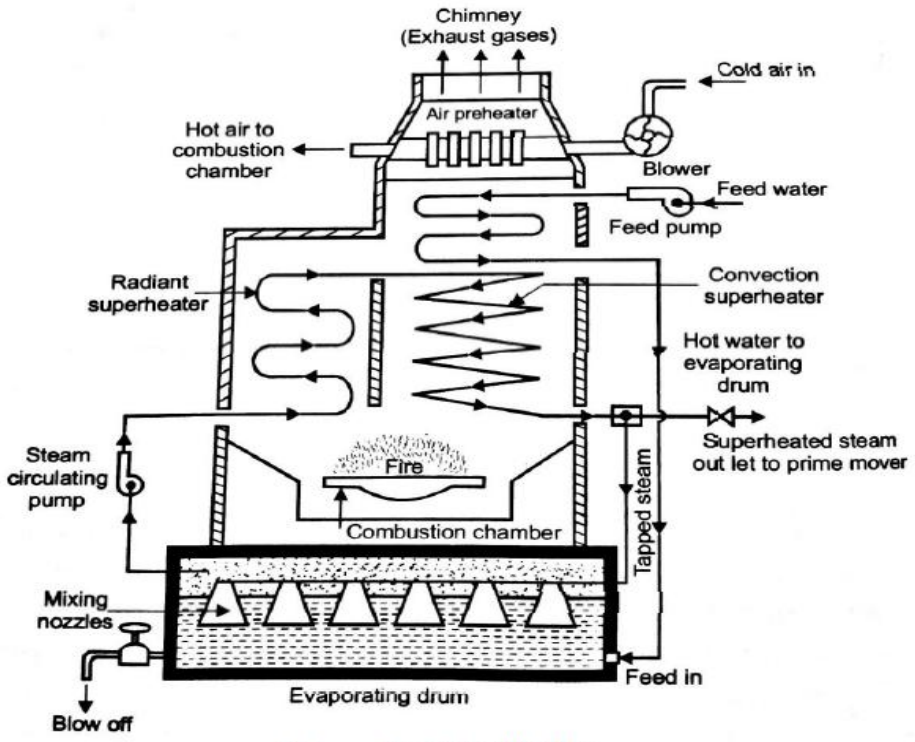


Fig . Loeffler Boiler

❖ The presser feed pump draws the water through the economizer and delivers it into the evaporator drum as shown in fig.

❖ About 65% of the steam coming out of super heater is passed through the evaporator drum are of special design and avoid priming and nice.

❖ This boiler can carry higher salt concentration than any other type and is move compact than indirectly heated boilers having natural circulation, these qualities fit it land or sea tram port power generation.

❖ Loffler boilers with gentling capacity of 100 tones/ hr and operating at 140 bar already commissioned.

BENSON BOILER(Nov/Dec 2016)

❖ The main difficulty experienced in the La Mont boiler is the formation and attachment of bubbles on the inner surfaces of the heating tubes.

❖ The attached bubbles to the surfaces reduced the heat flow a steam than wither film.

❖ Benson in 1922 argued that if the boiler pressure was raised to critical pressure (225 bars) the steam and water have the same density and therefore the danger of bubble development at the time didn't allow building turbine for such high pressure.

- The arrangement of the boiler components is shown in fig. the water as passed through the economizer in to the radiant evaporator is shown in figure where majority of water is converted into steam.

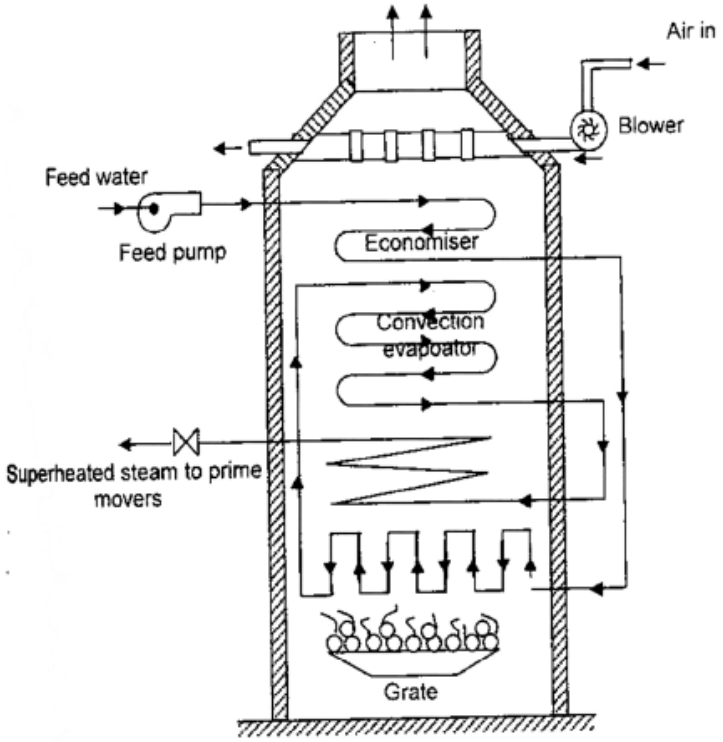


Fig . Benson Boiler

- The remaining water is evaporated in the final evaporator absorbing the heat from hot gases by convection.
- The saturated high pressure steam (at 225 bars) is further passed through the super heater as shown in fig.4.3
- Major difficulty to salt deposition was experienced in the transformation zone when all remaining water converted in to steam.
- To avoid this difficulty the boiler (final evaporator) is normal flashed out after every 4000 working hours to remove the salt.

Advantages:

- As there are no drums, the total weight of Benson boiler is 20% less then boilers this also reduces the cost of boiler.
- Natural circulation boilers require expansion joints but there are not required for Benson is the pipes are water.
- The creation of Benson boiler is easier and quicker as all the pasts are welded at sites and works hop job of tube expansion is altogether avoided.
- The transfer of Benson's part is easy as no drums are required and majoring of the path are carried to the site without pre assembly
- The Benson boiler can be erected in the comparatively smaller floor area. The space problem does not control the size of Benson boiler used.
- The furnace walls of the boiler can be more efficiently protected by using smaller diameter and close pitched tubes.
- The super heater in the Benson boiler is an integral part of forced circulation system, therefore no squired arranges mint for super heater is required.
- The Benson boiler can be started very quickly because of welded joints.

VELOX BOILER:

❖ The arrangement of the components of velox-boiler is shown in fig. Air is compressed to 2.5 bars with the help of a compressor run by gas turbine before supping to the combustion chamber to get.

❖ The supersonic velocity of the gases passing through the combustion chamber and gas tubes and high great release rates (35 to 45 million kJ/m^3).the burned gases in the combustion champer are passed through the annual of the tubes as shown in fig.

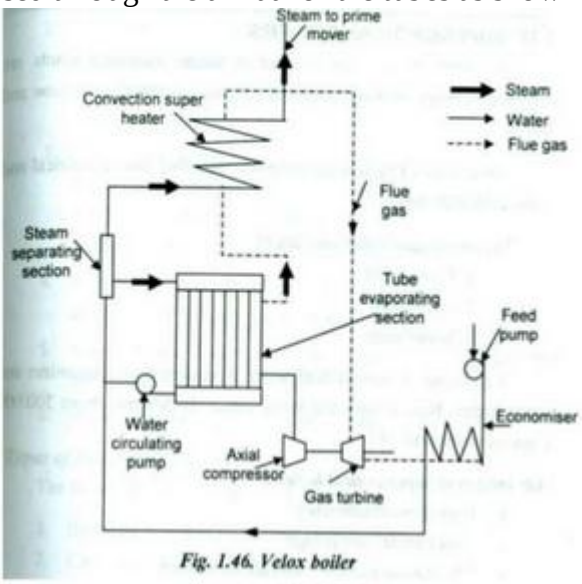


Fig 4.4 Velox Boiler

❖ The heat is transferred from gases to water while passing through the annual to generate the steam.

❖ The mixture of water and steam thus passes into a separator which is so designed that the mixture enters which a spinal flow.

❖ The centrifugal force thus produced causes the heavier water particles to be thorn out and on the walls.

❖ The effect separates the steam from water, the separated steam is further passed to Superheated and then supplied to prime mover.

❖ The water removed from steam in the separator is again passed into the water tubes with help of a pump.

❖ The gases coming out from the annuals at the top are further passed over the super heater where top are heat is used for superheated the steam the gases coming out of superhot meter are used to run a gas turbine as they carry sufficient kinetic energy .the power output of the gas turbine is used to run the air –compressor.

❖ The exhaust gases coming out from the gas turbine are passes thermal the economizer to utilize are the remaining heat of gases. the extra pore required to run the compression is supplied with the help of election motor .feed water of 10 to 25 time of weight of steam generated is circulated through the tubes with help of water circulating puling .

5.Explain in detail the coal handling system with suitable coal handing system or block diagram [Dec 2010] (or) Explain the various steps involved in "in plants coal" handling in thermal power.(or) Name the various equipments used for transferring the coal. Explain the working of any one Equipment. (Dec 2011)(April/May 2011)(DEC 2012) or Explain the types of coal handling system? Write any one method with neat flow diagram? (Nov/Dec 14), (Apr/May 2017) (APR/MAY 2018)

Coal handling system:

❖ In plant handling system deals with the processing of after receiving the coal from the coal mines at the plant site

❖ The in plant coal handling system should be designed such a way that the in plant

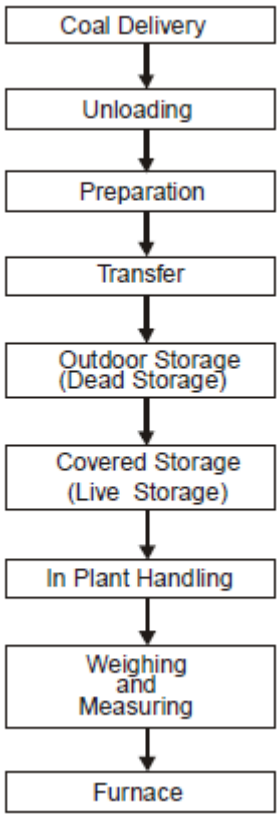
transportation should be minimum.

(i)Coal delivery:

- Coal from their supply point is generally carried out by the following modes
  a) Ships or boats, if site is situated near the sea or river
  b) Rails, if sea is away from sea or river

ii)**Unloading**

- Selection of suitable unloading equipment depends on the out plant handling
- If coal is delivered by ship or boats, then portable conveyers, unloading bridges, coal towers, self unloading boats and coal accelerator are used as unloading devices



Steps in coal handling

iii)**Coal preparation**

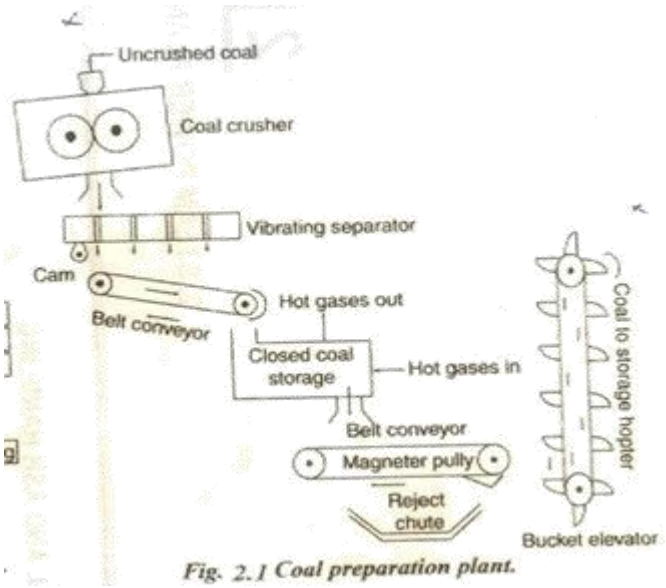


Fig. 2.1 Coal preparation plant.

- The coal preparation plant which include crushers, breakers, dryers, sizers and magnetic

separators.

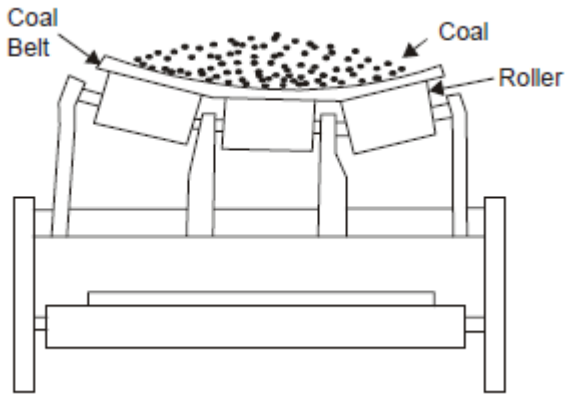
- ❖ Coal is prepared to suitable condition such that it ensures efficient combustion process.
- ❖ Coal form the mines is given to coal crusher for preparing it into required size

iv) Coal transfer

The equipment include

- Belt conveyer
- Screw conveyer
- Bucket conveyer
- Grab conveyer

A)Belt conveyer



- ➢ Belt conveyer is a flexible type hoisting and conveying device used for transporting large quantities of coal over a large distance
- ➢ The load carrying capacity of the belt conveyer may vary from 50 to 100 tonnes per hour

Advantages

1.Low power consumption
2.Lesser repair maintenance cost

Disadvantages

1. Not suitable for greater heights and short distances
2. Installation and replacement of belt is very costly.

B) **Screw conveyer**

➢ It consists of an endless helicoids screw fitted to a shaft, one end of the shaft is connected with the driving mechanism and the other end is supported is an enclosed ball bearing

Advantages

1. Unit is simple compact and dust proof
2. Low initial cost requires minimum space

Disadvantages

1. High power consumption
2. Excessive wear and tear which reduces the life of the screw conveyer

C) Bucket elevators

- ➢ It consists of buckets fixed to a chain (Fig. 4.5). The chain moves over two wheels.
- ➢ The coal is carried by the buckets from bottom and discharged at the top.

Advantage:-

1. Less power is required
2. Coal can be discharged at elevated space
3. Less area is required.

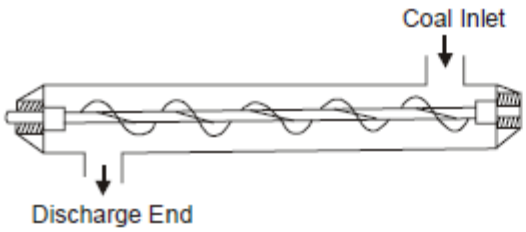


Fig. 4.4. Screw Conveyor.

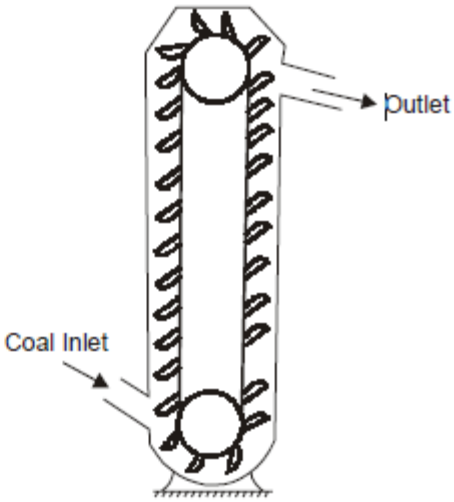


Fig. 4.5. Bucket Elevator.

d) Grab bucket elevator

- Grab bucket elevator is a device used for both lifting and convey coal on a single rail or track from one point to other

iv)Outdoor storage

❖ Outer storage or dead storage can be open space in one corner of the plant. Its capacity can be six months or one year requirement of the plant

v)Covered storage

❖ Live storage or covered storage is a space provided in the plant near the boiler furnace to meet one day requirement of the plant.

❖ Live storage can be provided of with bunkers and coal bins

vi) In plant handling

❖ Handling of coal from storage to firing equipment is known as in plant handling of coal

vii) Weighing and measuring

❖ It is necessary t weigh the coal at the unloading point and the supply quantity to individual boiler in order to run the plant in an economical manner.

6. **What are the operations involved in ash handling system? (Nov/Dec 2010)(May/June 2012)(DEC 2012) or Enumerate various modern ash handling system. (May/June 14) or Write a short notes on: ash handling system.(Nov/dec 15),),(Apr/May 2017) (APR/MAY 2018)**

The operations involved in ash handling system are

a. Removal of ash from furnace
b. Transfer of ash from furnace to isolated storage place.
c. Disposal of stored ash.

Some of the places to dump huge amount of ash:

- The barges may be used for dumping ashes in se.
- Disused quarries provided it should be within reasonable distance.
- Can be used for road making or to fill low lying areas. Deep ponds may be constructed

Ash handling systems:

The modern handling system used in steam power plants are,

1. Mechanical system
2. Hydraulic system
3. Pneumatic system
4. Steam jet system

Mechanical system:

❖ Mechanical handling system is a continuous discharge system used for capacity coal fired power plants.

❖ In this system, ash is cooled by allowing it to fall over the conveyor through a water seal.

❖ The cooled ash is then carried continuously to a dumping site

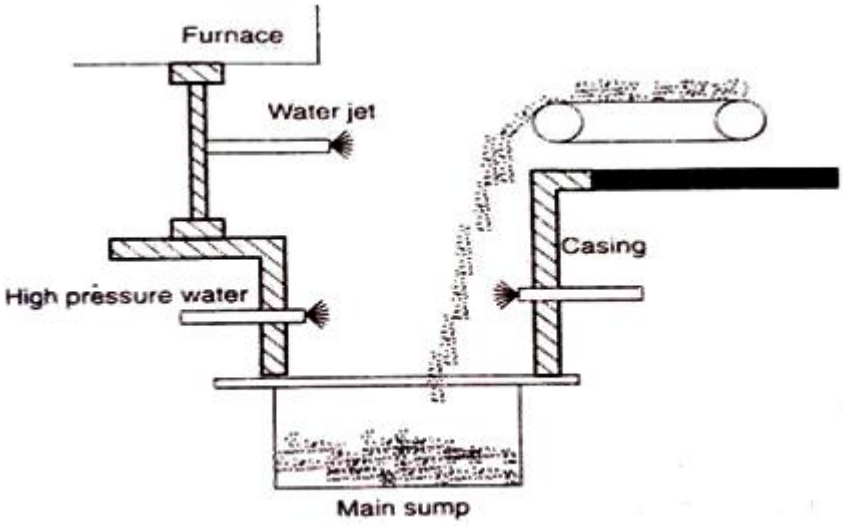


Fig 7.1 Mechanical System

Hydraulic system:

This system classified into two types

1.High pressure system
2. Low pressure system

High pressure system:

❖ In this system hoppers below furnace are fitted with water nozzle at the top and at sides.

❖ Ash is quenched by top nozzles and it is derived by side nozzles.

❖ The cooled ash and high velocity water is than flow through trough to the sump where the ash and water are separated.

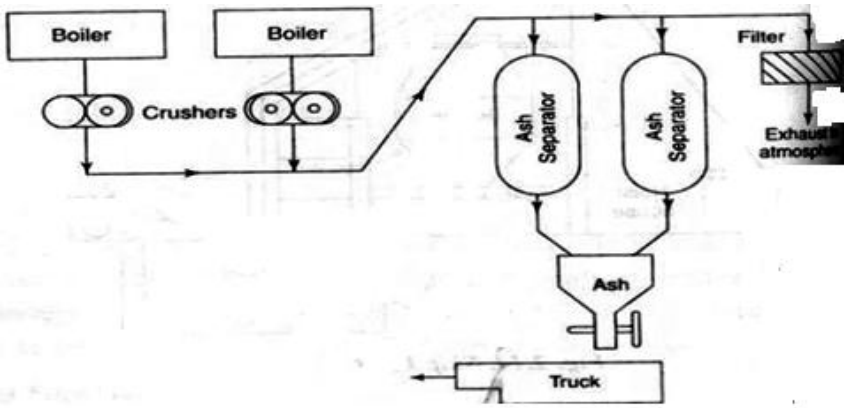


Fig 7.2 Hydraulic system

Low pressure system:

- In this system, a trough is provided below the boiler furnace and water at low velocity is made to through it.
- Ash directly falling into the trough is carried by the water to the sump.
- In the sump, the ash is separated from water with the help of screen and water is pumped back to the trough.

Pneumatic system:

- In this system air is used as a medium for driving the ash through a pipe.

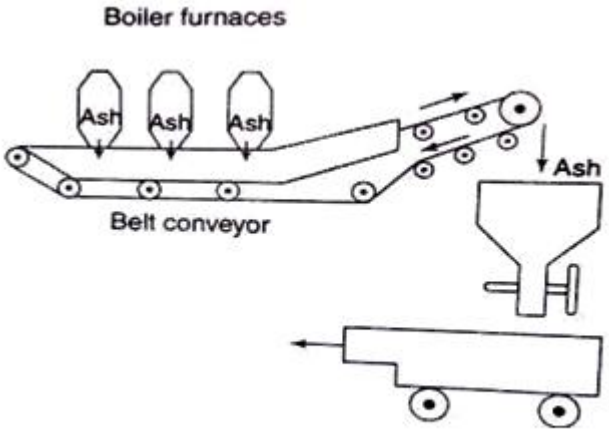


Fig 7.3 Pneumatic System

- Ash from the boiler is crushed and passed into a steam of air.
- The primary & secondary air removes ash and discharged through the hopped while clean air is exhausted to the atmosphere .
- For handling fine abrasive ash as well as fine dusty material

Steam jet system:

- As this system high pressure system jet is used for driving the ash along the conveying pipe.
- This system is employed in small and medium size plants where the path of travel of ash is not straight and space available is not sufficient for other system.
- This system operator at high were due to abrasive action of ash which acquires the conveying pipe to be lined with nickel alloy.

7**. What is meant by super heater? Describe its classification. Or Explain with neat sketch about the following: super heater. (nov/dec 14) or Discuss the function of air heater types.(May/june 16)**

Super heater:

❖ The super heater is a heat exchanger in which heat is transfixed to the saturated steam to increase its temperature it raises the overall cycle efficiency.

❖ They are classified as follows:

- Convective.
- superheated Radiant
- superheated Pendant
- super heaters

❖ Upper haltered steam boilers built the water and further heat the steam in a superheated .thesis provides steam at much higher temperature but can decrease the overall thermal officially of the steam generating plant due to the fact that the higher flue gases exhaust temperature .there care serial ways to a circumvent this problem typically by providing a feed what heaving"economizer" and /or a combustion air hearten in the falling hot flue gases exhaust paths

1. Convective super heater:

It is located in the path of the hot gases. (Absorb heat via flied i.e.Gas)

2. Radiant superheat:

It is placed directly in the combustion chanter (absorb heat by radiation)

3. Pendant super heater:

It is totality separated from the boiler.

Whether by conversion or radiation the extreme heat in the boiler furnace / flue gas path will also heat the super heater steam piping and the steam within as well.

8.Explain with the aid of sketches of forced Draft System and induced draft system or what is the main function of draught system? (Nov/Dec 2010)(May/June 2012) or what do you understand the term boiler draught.(May/June 14) or Write short note on:Different draught system.(Nov/dec 15).

Draught system:

❖ Draught is defined as the difference between absolute gas pressures at any point in a gas flow passage and the ambient atmospheric pressures measured at same elevation.

❖ The difference between atmospheric pressure and the pressure existing in the furnace or flue gas passage of a boiler is termed as **draft.**

❖ This pressures difference is required to maintain the constant flow of air and discharges gas through chimney to atmosphere

❖ To supply sufficient quantity of air through the furnace for complete combustion of fuel.

❖ To remove gaseous products of combustion from the furnace .

❖ To move and exhaust he products of combustion to the atmosphere through the chimney

Classification of draught system

1. Natural draught (chimney)
2. Artificial draught (mechanical)
   (a) Forced draught
   (b) Induced draught
   (c) Balanced draught

Natural draught system:

❖ Natural draught system consists of a tall chimney and suitable is only for small capacity belles

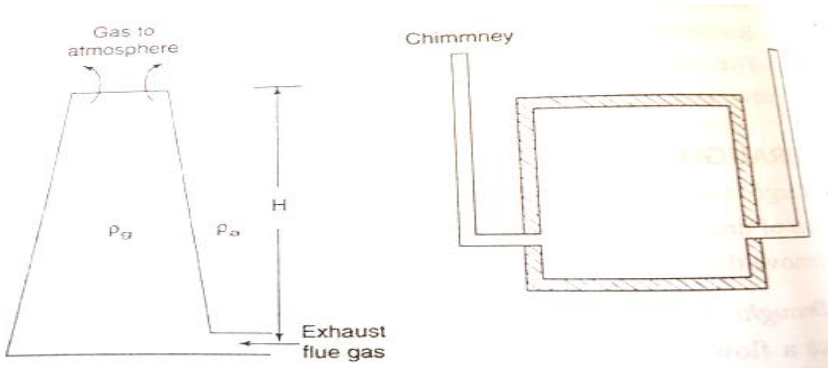


Fig 8.1 Natural draught system

❖ The draught is caused by the chimney due to the temperature difference and pressure difference of hot gases inside the chimney and air outside the chimney.

❖ This pressure difference causes the flaw of air into the furnace pushes the hot gases though the chimney

$$\Delta p = gH(\rho_g - \rho_g)$$

Δp =Pressure difference

Forced draught system:

❖ In this system ,a fan is located before the furnace is near the base of the boiler .it discharge air under pressure into the furnace and to attack of chimney through the economies air preheated

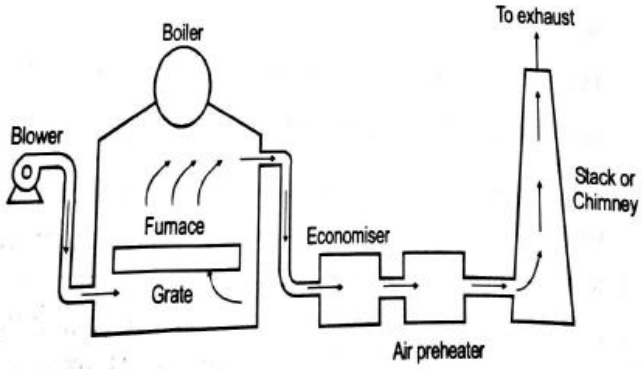
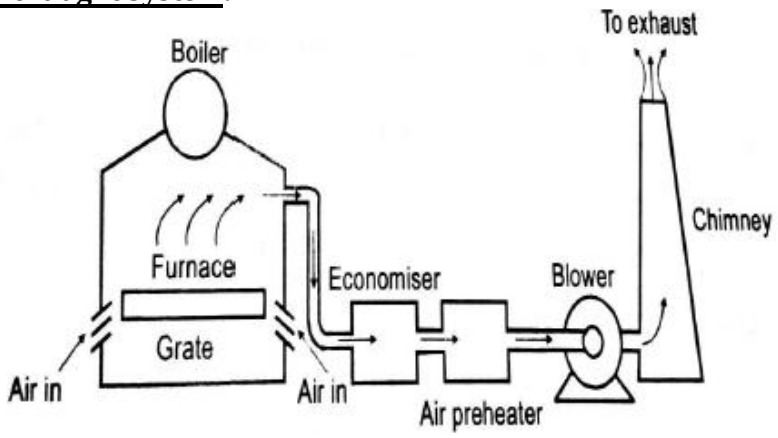


Fig Forded draught system

❖ The pressure inside the system is higher than the atmospheric pressure and hence it is also called as positive draught system.

Induced draught system:



❖ In this system (ID fan) fan is located near the chimney base sure such that it draws the burnt gases form the furnace and bolus in to the chimney

❖ This results in pressure drop in the furnace and cerates parties volume due to which , atmospheric air flows through the furnace freely.

❖ The flues gases may be discharged as cold as possible after recovering its heat in air preheated and economics

Balanced draught system:

❖ In is the combination of forced draught to induced draught system. When the furnace of a FD system is opened for firing or inspection.the high pressure air try to escape suddenly and the furnace may stop.

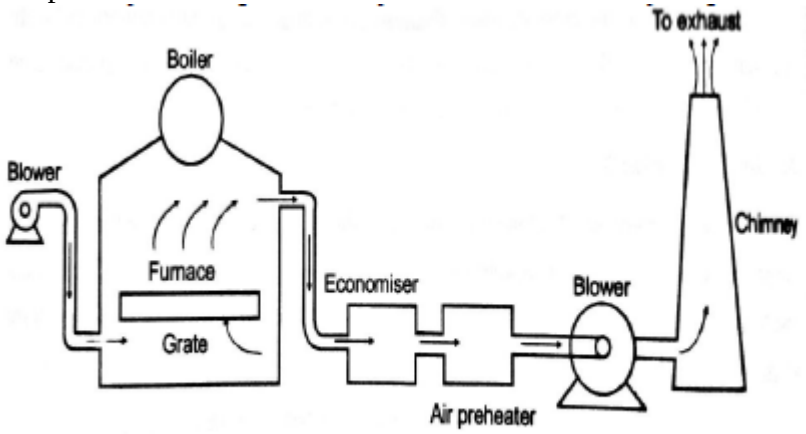


Fig Balanced draught system

❖ When the furnace of an ID system is open for firing cold air tries to enter into the furnace due to partial velum created in the furnace.

9. What is mean by steam condenser explain about briefer their cassation. Or Describe with neat sketches the operation of the following Condensers.(i)Jet condenser (ii)Evaporative condenser.(may/june 15) or Explain the arrangement and operation of a surface condenser.(may/june 16)

Steam condensers:

❖ A steam condensers is a closed vessel heat exchanger by absorbing steam coming from trubine is condensed by absorbing the heat from steam by continuous supply of cooling water at atmospheric temperature.

Functions of steam condenser:

❖ The function of steam condenser is to decrease the exhaust pressure of steam below the atmospheric level.

❖ To recover high quality feed water in its original form and feed in back to the steam generator without any further treatment.

❖ This eliminates the cost involved in treatment process for the supply of fresh water.

Elements of a steam condenser plant

❖ Closeted vessel heat exchanged.
❖ Supply of cooling water to absorb the heat from steam.
❖ Pump to circulate the cooling water.
❖ Condensate extraction pump
❖ Hot wall to discharge condensate
❖ Air extraction pump
❖ Cooling rower to recoil the water

Classification of condensers

They are classified into two types

1. Surface condenser (or) non-mixing condensers
    (a) Down flow surface condenser
    (b) Central flow surface condenser
    (c) Inverted flow surface condenser
    (d) Evaporative condenser
    (e) Regenerative surface condensers
2. Jet condensers (or) mixing condenser
    (a) Low level parallel flow jet condenser
    (b) Low level counter flow jet condenser
    (c) high level or barometric jet condenser
    (d) Ejector jet condenser

❖ In jet condensers the exhaust steam and cooling water come in direct contact with each other.

❖ The temperature of cooling water and the condensate is same when leaving the condensers.

Elements of the jet condenser are as follows:

1. Nozzles or distributors for the condensing water.
2. Steam inlet.
3. Mixing chambers: They may be (*a*) parallel flow type (*b*) counter flow type depending on Whether the steam and water move in the same direction before condensation or whether the flows are opposite.
4. Hot well.

In jet condensers the condensing water is called injection water.

Low level jet condensers (Parallel flow type).:

❖ In this condenser (Fig. 9.1) water is sprayed through jets and it mixes with steam.

❖ The air is removed at the top by an air pump. In counter flow type of condenser the cooling water flows in the downward direction and the steam to be condensed moves upward.

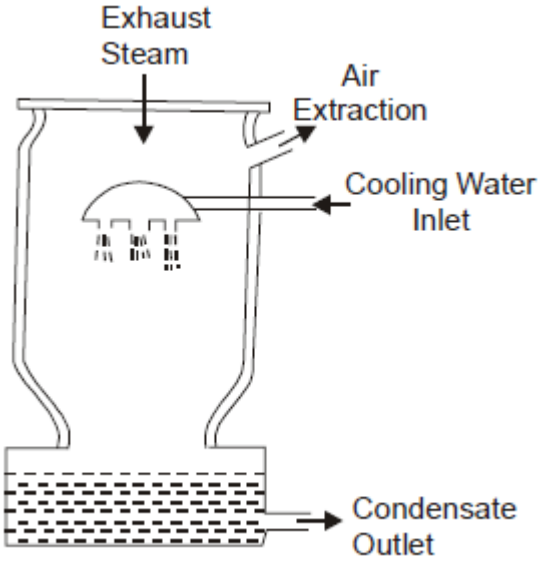


Fig. 9.1 Low level jet condensers

High level or Barometric condenser.

❖ Fig. 9.2 shows a high-level jet condenser. The condenser shell is placed at a height of 10.33 m (barometric height) above the hot well.

❖ As compared to low level jet condenser. This condenser does not flood the engine if the water extraction pump fails. A separate air pump is used to remove the air.

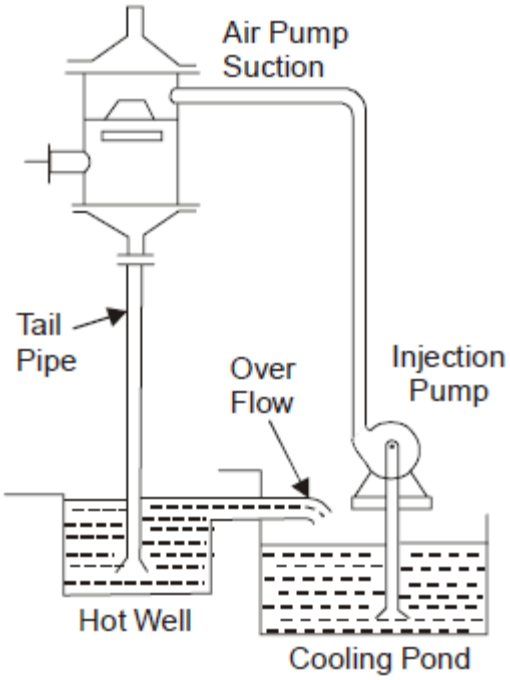


Fig 9.2 High level or Barometric condenser

Ejector Condenser.

❖ Fig. 9.3 shows an ejector condenser. In this condenser cold water is discharged under a head of about 5 to 6 m through a series of convergent nozzles.

❖ The steam and air enter the condenser through a non-return valve. Mixing with water condenses steam.

❖ Pressure energy is partly convert into kinetic energy at the converging cones. In the diverging come the kinetic energy is partly converted into pressure energy and a pressure higher than atmospheric pressure is achieved so as to discharge the condensate to the hot well.

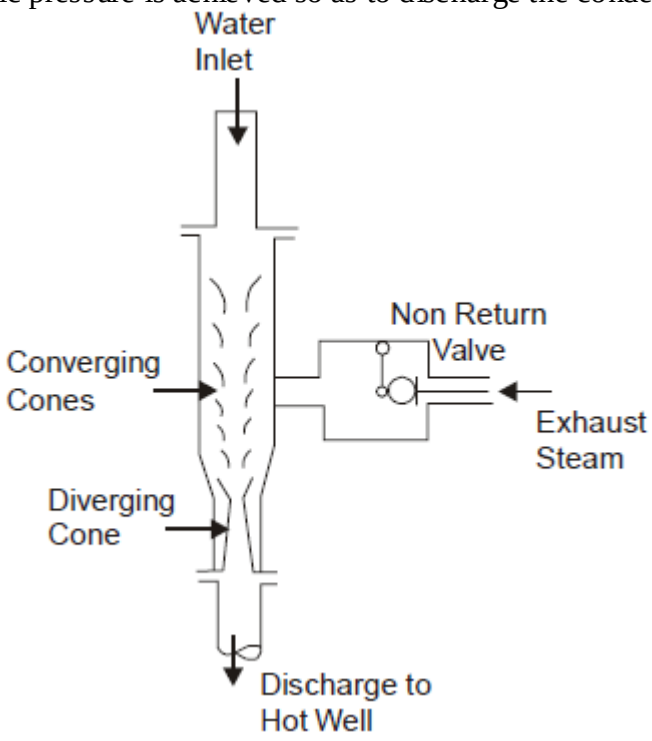


Fig 9.3 Ejector Condenser

Down flow (two–pass) surface condensers:

❖ It is composed of a steal shell with water boxer on each side. The water bon at the right and is decided in two parts by a baffle plate to allow the water for two passes

❖ A section of the tubes near the air pump suction is screened off by providing a baffle as

shown in fig. the no of tube used in this section per unit area are more compared with other part of the condenser.

❖ The velocity of water through these tubes is also maintained higher .this is done to reduce the amount of steam going along with air the intensive cooling of air in this section increases the density of air going out and reduces the capacity of air pump (size) required by as much as 50%.

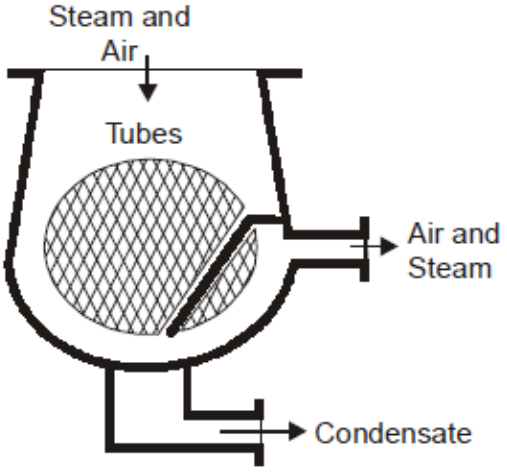


Fig 9.5 Sectional view of down flow condenser

❖ The surface condenser requires 3 pumps when it works on its day vacuum system.

❖ One for circling the cooling tower, one for enticing the condensate and third is required for removing the air the surface condenser requires only two pumps it works on wet vacuum system.

❖ one for circulating the cooling water and other for extracting the air and condensates to gather .these types of condensers are widely used for high capacity of power plant.

❖ A two pass down .flow surface condemner already shown in fig. 9.6sectional view of down flow condenser shown in fig.

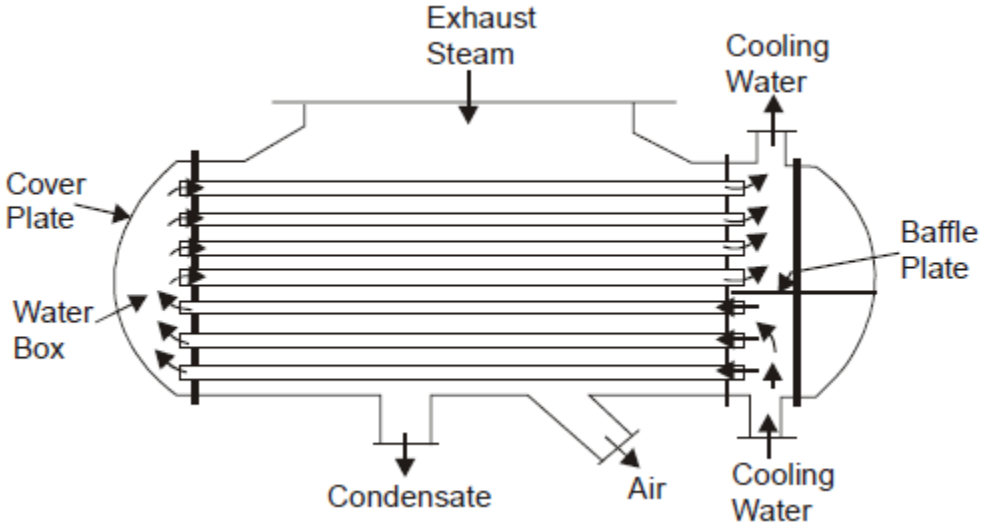


Fig 9.6 longitudinal section view of two pass down-flow condenser

❖ The steam enters from the top and flows mainly download over the tubes .the air is extracted at lower temperature then the condensate by providing a separate cooling section known as air cooler.

Central flow condenser:

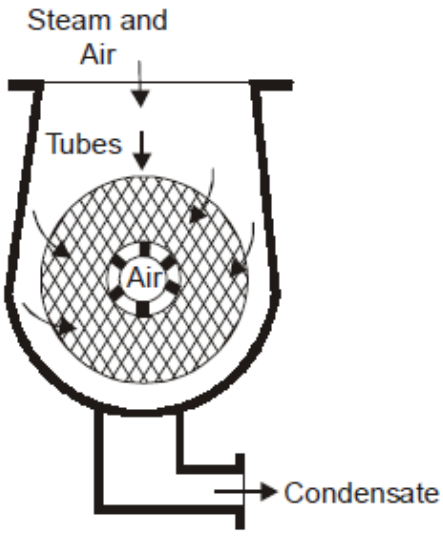


Fig 9.7 central flow condenser

❖ A sectional view of central flow condenser shown in fig. in this arrangement, the air cooling section is provided at the centre of the tube nest and air is extracted from this section. This arrangement causes the steam to flow radically.

❖ Towards the centre and passes over the entire periphery of tubes.

❖ The formed condense is extracted from batten as shown in fig. this arrangement is an improvement over down wade flow type case it has an access to the whole periphery of the tube.

Evaporative condenser:

❖ These condensers are more preferable where acute shortage of costing water exist the arrangement of the condense as shown if fig. after is sprayed throughthe nozzles over the pipe carrying exhaust steam and from a thin flam over it.

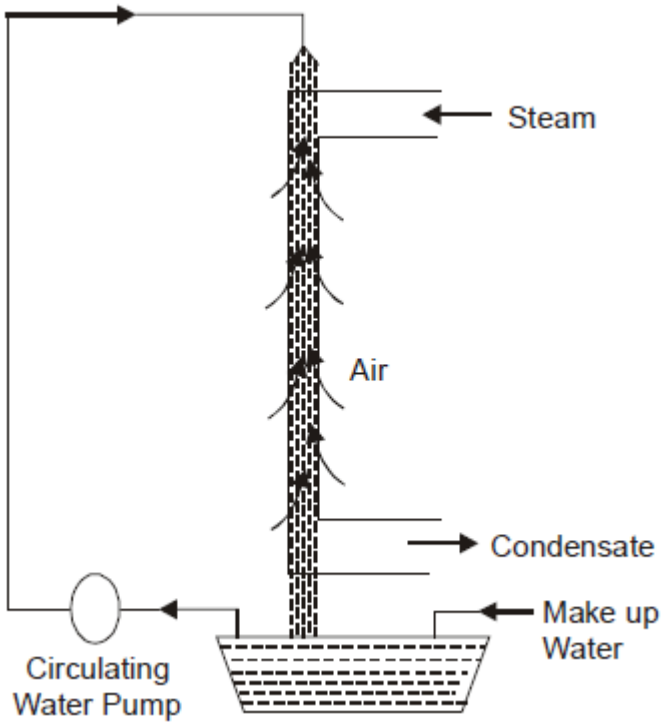


Fig 9.8 Evaporative condenser

❖ The air is drawn over the surface of the coil with the help of induced fan as shown in Fig. the air passing over the coil carries the water from the surface of condenser coil in the form of vapour.

❖ The latent heat required for the evaporation of water vapour is taken from the water

film formed on the condenser coil and drops the temperature of the water film and this helps for heat transfer from the steam to the water .

❖ This mode of heat transfer reduces the cooling water requirement of the condenser to 10% of the requirement of surface condenser .

❖ The water particles carried with the air due to high velocity of air is removed with help of eliminators as shown in Fig. The makeup water (water vapour and water particles carried with air) is supplied from outside source.

10. Explain in detail about hyperbolic cooling tower. (Or) How Cooling towers are classified? Explain anyone with neat sketch (April/May2010), Explain briefly the air cooled cooling system (May/June 2013))(Apr/May 2017)

Cooling Towers have one function:

❖ Remove heat from the water discharged from the condenser so that the water can be discharged to the river or re circulated and reused.

Cooling Tower

❖ A cooling tower extracts heat from water by evaporation. In an evaporative cooling tower, a small portion of the water being cooled is allowed to evaporate into a moving air stream to provide significant cooling to the rest of that water stream.

❖ Cooling Towers are commonly used to provide lower than ambient water temperatures and are more cost effective and energy efficient than most other alternatives.

❖ The smallest cooling towers are structured for only a few liters of water per minute while the largest cooling towers may handle upwards of thousands of liters per minute.

❖ The pipes are obviously much larger to accommodate this much water in the larger towers and can range up to 12 inches in diameter.

❖ When water is reused in the process, it is pumped to the top of the cooling tower and will then flow down through plastic or wood shells, much like a honeycomb found in a bee's nest.

❖ The water will emit heat as it is downward flowing which mixes with the above air flow, which in turn cools the water. Part of this water will also evaporate, causing it to lose even more heat.

Types of Cooling Towers

❖ Open cooling towers, also called direct cooling towers, allow the water to come into contact with outside air.

❖ If cooled water is returned from the cooling tower to be used again, some water must be added to replace the water that has been lost.

❖ Pollutants are able to enter into the water used in these processes and must be filtered out.

❖ Closed loop (or closed circuit) cooling tower systems, also called indirect cooling tower systems, do not allow the water to come into contact with any outside substance, therefore keeping the water more pure due to the lack of foreign particles introduced.

Natural Draft Towers

❖ Natural draft towers are typically about 120 m high, depending on the differential pressure between the cold outside air and the hot humid air on the inside of the tower as the driving force. No fans are used.

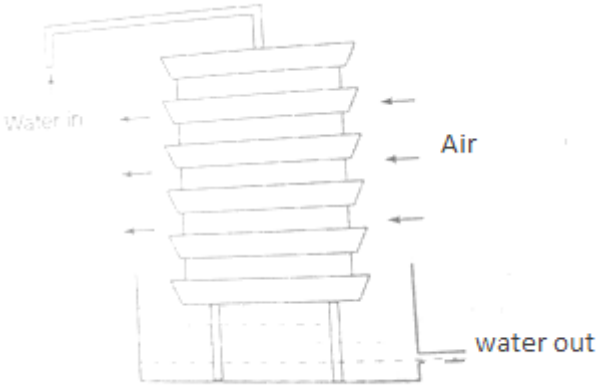


Fig 10.1 Natural Draft tower

❖ Whether the natural or mechanical draft towers are used depends on climatic and operating requirement conditions.

❖ The green flow paths show how the warm water leaves the plant proper, is pumped to the natural draft cooling tower and is distributed.

❖ The cooled water, including makeup from the lake to account for evaporation losses to the atmosphere, is returned to the condenser.

Mechanical Draft

❖ Mechanical draft towers uses fans (one or more) to move large quantities of air through the tower. They are two different classes:

(a) Forced draft cooling towers
(b) Induced draft cooling towers

Forced Draft

❖ The forced draft tower has the fan, basin, and piping located within the tower structure. In this model, the fan is located at the base.

❖ There are no louvered exterior walls. Instead, the structural steel or wood framing is covered with paneling made of aluminum, galvanized steel.

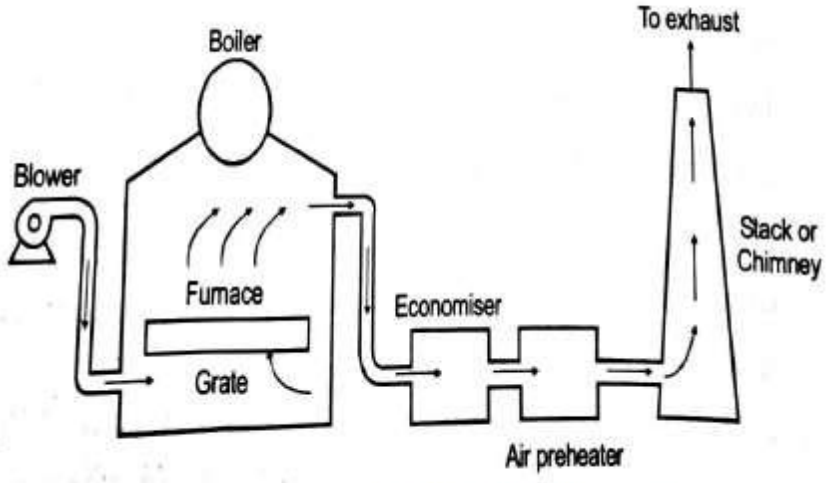


Fig Forded draught system

Fig 10.2 Forced Draft tower

❖ During operation, the fan forces air at a low velocity horizontally through the packing and then vertically against the downward flow of the water that occurs on either side of the fan.

❖ The drift eliminators located at the top of the tower remove water entrained in the air. Vibration and noise are minimal since the rotating equipment is built on a solid foundation.

❖ The fans handle mostly dry air, greatly reducing erosion and water condensation

problems.

Induced Draft

❖ The induced draft tower show in the following picture Fig 10.3 has one or more fans, located at the top of the tower, that draw air upwards against the downward flow of water passing around the wooden decking or packing.

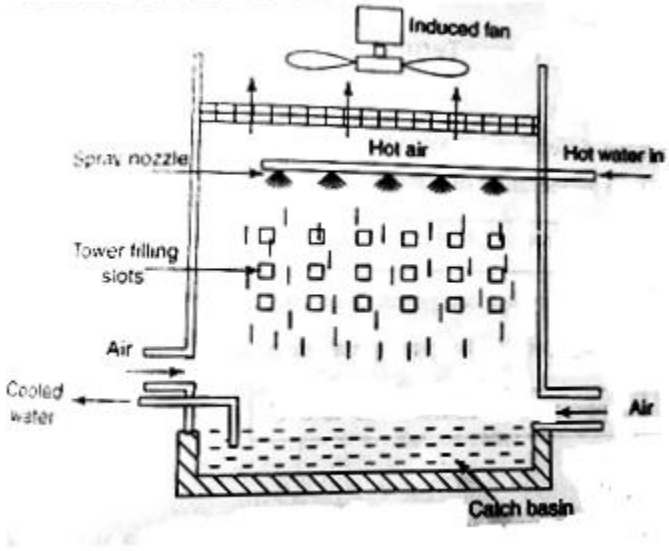


Fig 10.3 induced draft tower

❖ Since the airflow is counter to the water flow, the coolest water at the bottom is in contact with the driest air while the warmest water at the top is in contact with the moist air, resulting in increased heat transfer efficiency.

Hyperbolic cooling tower

❖ Hyperboloid (hyperbolic) cooling towers (Image 1) have become the design standard for all natural-draft cooling towers because of their structural strength and minimum usage of material.

❖ The hyperboloid shape also aids in accelerating the upward convective air flow, improving cooling efficiency. They are popularly associated with nuclear power plants.

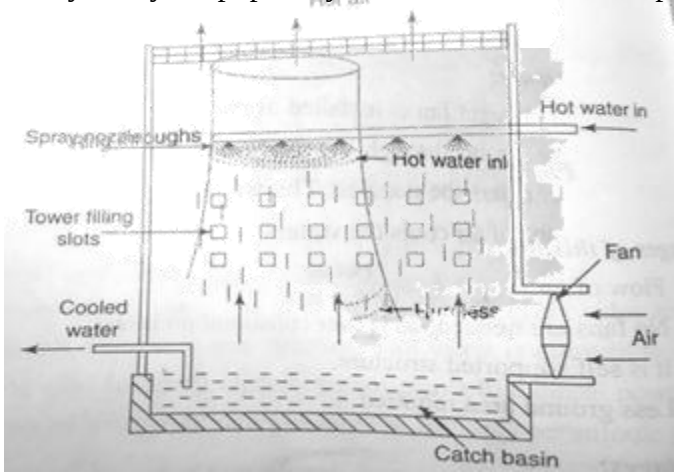


Fig 10.4 Hyperbolic Cooling Tower

❖ However, this association is misleading, as the same kind of cooling towers are often used at large coal-fired power plants as well.

❖ Similarly, not all nuclear power plants have cooling towers, instead cooling their heat exchangers with lake, river or ocean water.

11. Describe the Different types of over feed Stokers and discuss the merits and demerits of each over others (May 2013)

❖ The stokers are used to feed solid fuels into the furnace in medium and large size power plants.

Types of overfeed Stokers:

1. Chain Grate Stoker.
2. Spreader Stoker.

Chain Grate Stoker:

❖ Chain grate stoker and traveling grate stoker differonlyin grate construction. A chain grate stoker (Fig. 4.16) consists of an endless chain which forms a support for the fuel bed.

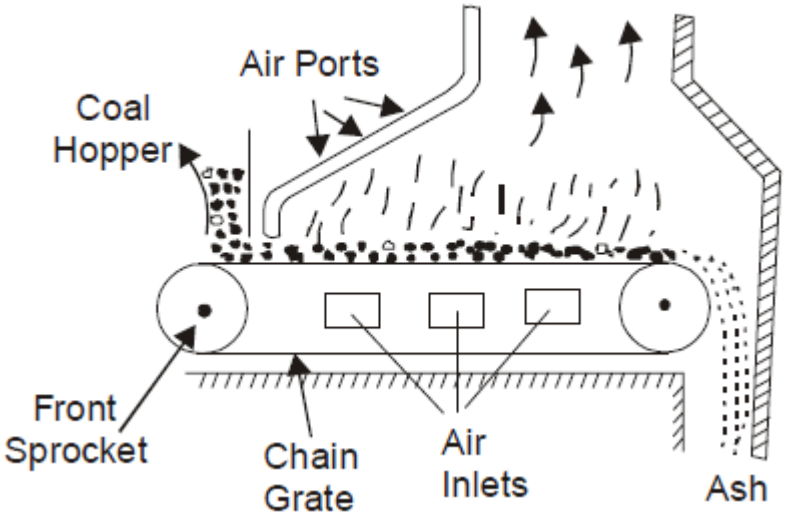


Fig 11.1 Chain Grate Stoker

❖ The chain travels over two sprocket wheels, one at the front and one at the rear of furnace. The traveling chain receives coal at its front end through a hopper and carries it into the furnace.

❖ The ash is tipped from the rear end of chain. The speed of grate (chain) can be adjusted to suit the firing condition. The air required for combustion enters through the air inlets situated below the grate.

❖ Stokers are used for burning non-coking free burning high volatile high ash coals. Although initial cost of this stoker is high but operation and maintenance cost is low.

❖ The traveling grate stoker also uses an endless chain but differs in that it carries small grate bars which actually support the fuel fed. It is used to burn lignite, very small sizes of anthracites coke breeze etc.

❖ The stokers are suitable for low ratings because the fuel must be burnt before it reaches the rear of the furnace.

❖ With forced draught, rate of combustion is nearly 30 to 50 lb of coal per square foot of grate area per hour, for bituminous 20 to 35 pounds per square foot per hour for anthracite.

Spreader Stoker:

➢ In this system the coal is feed to through the feeder. The feeder arrangement has rotating drums with blades.

➢ The speed of the feeder can be changed as per the level of the plant. From the feeder, the coal is dropped over the spreader distributor which spreads the coal over the furnace.

➢ The spreader consists of a rapidly rotating shaft carrying blades. These fast rotating blades with the coal particles are coming from the feeder and throw it into the furnace.

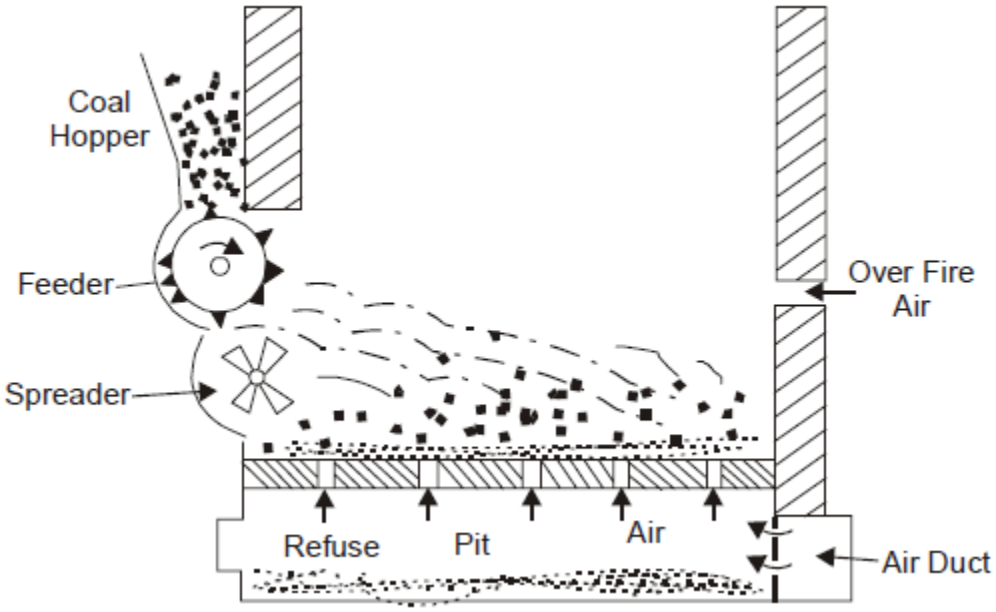


Fig11.2 Spreader Stoker

Advantages:

1. Variety of coal can be used to burn in this stoker.
2. Cooling of Ash is easier because of incoming air is under the ash.
3. Less operating cost.
4. It is very useful for fluctuating loads.

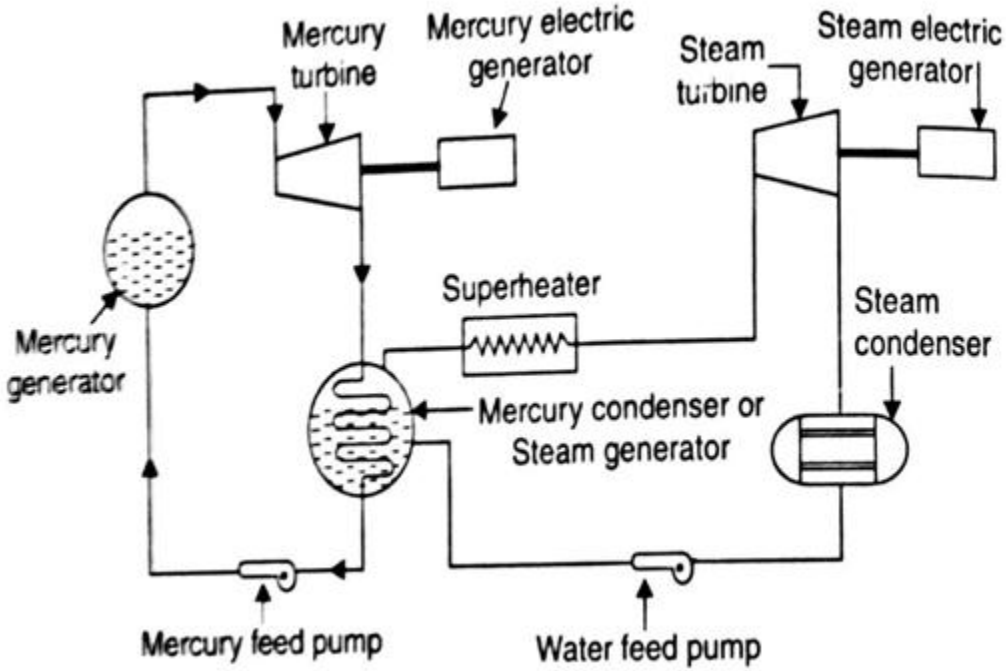
Disadvantages:

1. It is not suitable for large size coal.
2. It requires dust collecting equipment.

12. Explain Binary Vapour Cycle?

Binary Vapour Cycle

❖ No single fluid can meet all the requirements of vapour power cycle.Normally water is good working fluid of vapour power cycle.But in high temperature range,there are few better fluid available,such as diphonyl ether,aluminium bromide and mercury.



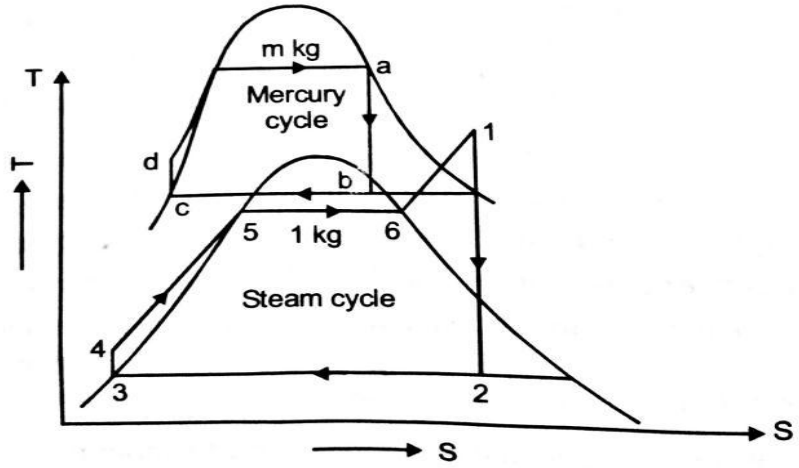
❖ Among these,fluids,mercury is widely used as working fluid because it does not decompose gradually at high temperature.

❖ In this cycle two working fluids are used. Fig. 15.1 shows Elements of Binary vapour power plant.

❖ The mercury boiler heats the mercury into mercury vapours in a dry and saturated state. These mercury vapours expand in the mercury turbine and then flow through heat exchanger where they transfer the heat to the feed water, convert it into steam.

❖ The steam is passed through the steam super heater where the steam is super-heated by the hot flue gases. The steam then expands in the steam turbine.

T-S diagram of a binary vapour cycle



❖ For example,at pressure 12 bar,the saturation temperature of water is 187℃ and mercury 560℃.Mercury is thus a better working fluid at high pressure range,because at high temperature its vapourisation pressure is low.

❖ The critical pressure and temperature of mercury are 180 bar and 1460℃ respectively.

Process a-b-c-d-mercury cycle

It is simple Rankine cycle for mercury vapour.

Process a-b -Isentropic expansion of mercury in the turbine.

b-c -Mercury condensation.

c-d - Feed pmp(Mercury)

Process 1-2-3-4-5-6-steam power cycle.

Process1-2-Isentropic expansion of steam at turbine

2-3-condensation

3-4-Feed pump(water)

4-5-heating till it become a saturated vapour.

5-6-heat added to boil the water to form saturated vapour.

(The heat rejected from the mercury condenser is used generate steam in the steam power cycle).

6-1-The saturated steam is heated to form superheated steam by external source(furnace)

Let,m-Mass flow rate of mercury in the mercury cycle and the masss flow rate of steam is 1kg in steam power cycle.

The heat supplied in the mercury-steam power cycle

$$Q_1 = m(h_a - h_d) + (h_1 - h_6) + (h_5 - h_4)$$

The heat rejected $Q_2 = (h_2 - h_3)$

The mercury and steam turbine work,

$$w_T = m(h_a - h_b) + (h_1 - h_2)$$

The pump work(w_p),

$$w_p = m(h_d - h_c) + (h_4 - h_3)$$

$\eta_{Binary\ cycle} = \frac{Q_1 - Q_2}{Q_1}$ or $\frac{w_T - W_P}{Q_1}$

Steam rate = $\frac{3600}{w_T - W_P}$ kg/kw h

The energy balance of the mercury condenser –steam boiler,

$$m(h_b - h_c) = (h_6 - h_5)$$

$$m = \frac{(h_6 - h_5)}{(h_b - h_c)} \frac{\text{kg of mercury}}{\text{kg of water}}$$

To vapourise 1kg of water,seven to eight kg of mercury should condense.

13. Write a short note on co-generation systems.(Nov/Dec 2016)

Co-generation

- Cogeneration is also called as combined heat and power or combine heat and power.
- As it name indicates cogeneration works on concept of producing two different form of energy by using one single source of fuel. Out of these two forms one must be heat or thermal energy and other one is either electrical or mechanical energy.
- Cogeneration is the most optimum, reliable, clean and efficient way of utilizing fuel. The fuel used may be natural gas, oil, diesel, propane, wood, bassage, coal etc.
- It works on very simple principle i.e the fuel is used to generate electricity and this electricity produces heat and this heat is used to boil water to produce steam , for space heating and even in cooling buildings.
- In conventional power plant, the fuel is burnt in a boiler, which in turn produces high pressure steam.
- This high pressure steam is used to drive a tribune, which is in turn is connected to an alternator and hence drive an alternator to produce electric energy.
- The exhaust steam is then sent to the condenser, where it gets cool down and gets converted to water and hence return back to boiler for producing more electrical energy. The efficiency of this conventional power plant is 35% only.
- In **cogeneration plant** the low pressure steam coming from turbine is not condense to form water, instead of it its used for heating or cooling in building and factories, as this low pressure steam from turbine has high thermal energy.
- The **cogeneration plant** has high efficiency of around 80 - 90 %. In India, the potential of power generation from cogeneration plant is more than 20,000 MW.
- The first commercial cogeneration plant was built and designed by Thomas Edison in New York in year 1882

Need for Cogeneration

a) Cogeneration helps to improve the efficiency of the plant.

b) Cogeneration reduces air emissions of particulate matter, nitrous oxides, sulphur dioxide, mercury and carbon dioxide which would otherwise leads to greenhouse effect.

c) It reduces cost of production and improve productivity.

d) Cogeneration system helps to save water consumption and water costs.

e) Cogeneration system is more economical as compared to conventional power plant

Types of Cogeneration Power Plants

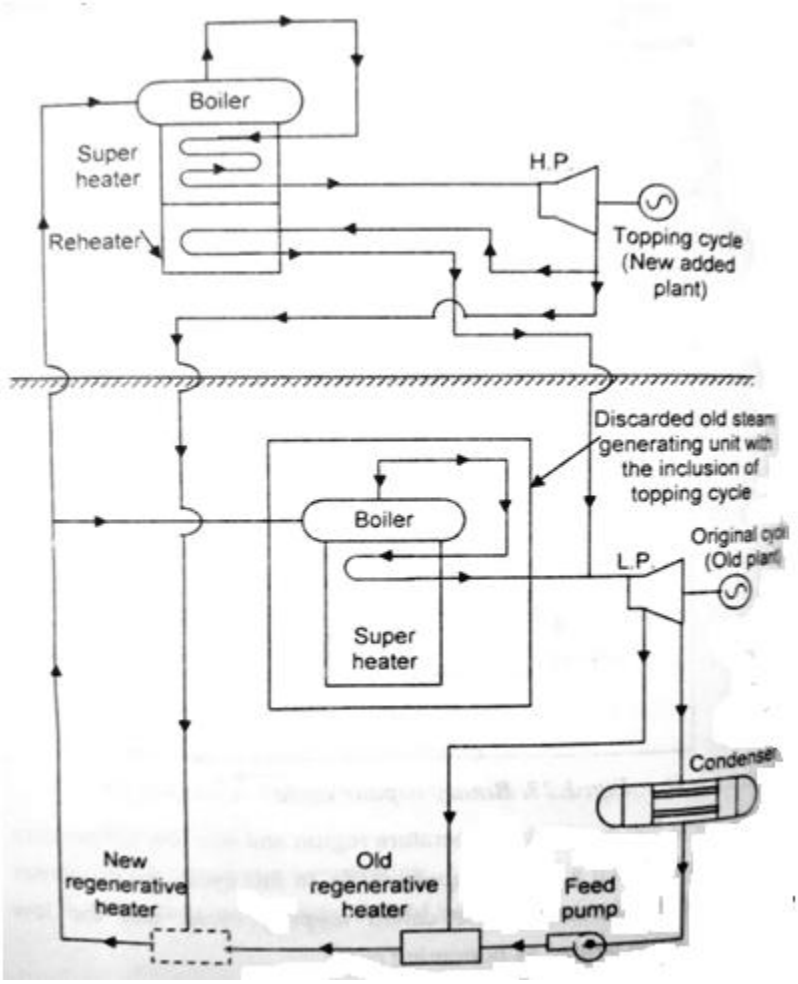
- In a typical Combined heat and power plant system there is a steam or gas turbine which take steam and drives an alternator.
- A waste heat exchanger is also installed in cogeneration plant, which recovers the excess heat or exhaust gas from the electric generator to in turn generate steam or hot water.

There are basically two types of cogeneration power plants, such as-

• Topping cycle power plant
• Bottoming cycle power plant

Topping cycle power plant:

❖ In this type of **Combine Heat and Power** plant electricity is generated first and then waste or exhaust steam is used to heating water or building . **There are basically four types of topping cycles.**



`3.1 Topping Cycle

a)Combined-cycle topping CHP plant –

❖ In this type of plant the fuel is firstly burnt in a steam boiler .

❖ The steam so produced in a boiler is used to drive turbine and hence synchronous generator which in turn produces electrical energy.

❖ The exhaust from this turbine can be either used to provide usable heat, or can be sending to a heat recovery system to generate steam, which maybe further used to drive a secondary steam turbine.

b)Steam-turbine topping CHP Plant-

❖ In this the fuel is burned to produce steam, which generates power. The exhaust steam is then used as low-pressure process steam to heat water for various purposes.

c)Water- turbine topping CHP Plant-

❖ In this type of CHP plant a jacket of cooling water is run through a heat recovery system to generate steam or hot water for space heating.

d)Gas turbine topping CHP plant-

❖ In This topping plant a natural gas fired turbine is used to drives a synchronous generator to produce electricity.

❖ The exhaust gas is sent to a heat recovery boiler where it is used to convert water into steam, or to make usable heat for heating purposes.

Bottoming cycle power plant:

- ❖ As its name indicate bottoming cycle is exactly opposite of topping cycle.
- ❖ In this type of CHP plant the excess heat from a manufacturing process is used to generate steam, and this steam is used for generating electrical energy.
- ❖ In this type of cycle no extra fuel is required to produce electricity, as fuel is already burnt in production process.

14. Explain in detail about purpose of boiler feed water treatment?

- ❖ All natural sources of water contain impurities as well as dissolved gases.
- ❖ The amount of these impurities depends on type of water source and location.

Necessary to treat the raw water?

- ❖ Raw water coming from different sources contains dissolved salts and un-dissolved or suspended impurities. It is necessary to remove harmful salts dissolved into the water before feeding it to the boiler.
- ❖ Because- (1) The deposition of dissolved salts and suspended impurities will form a scale on the inside wall of different heat-exchangers and thus there will create excessive pressure and thermal stress (due to uneven heat exchange across the wall of heat-exchanger) inside the heat-exchangers, which may lead to the explosion and serious hazards for boilers.

(2) The harmful dissolved salts may react with various parts of boiler through which it flows, thereby corrode the surfaces.

(3) Corrosion damage may occur to turbine blades.

The important water treatment process are:

1. Filtration
2. Coagulation and flocculation
3. Chemical precipitation
4. Reaction of lime soda in softening process
5. Ion exchange
6. Deaeration of water
7. Reverse osmosis
8. Internal treatment of boiler feedwater .

1. Filtration

❖ Filtration is the essential first step before the chemical treatment and conditioning of the boiler feed water.

❖ Filtration removes or minimizes all types of suspended solid impurities.

❖ If rust, sand (silica),chemical properties etc. are not filtered out, they lead to severe scale formation, which is difficult to clean and reduce boiler efficiency.

❖ Even the condensate feedwater must be filtered before returning to the boiler. The boiler itself and the steam piping produce rust particles etc. due to corrosion and other reactions.

2. Coagulation and flocculation

❖ If the suspended particles in water are so fine that even cartridge filters are unable to remove them. In such a situation, the water is first treated with coagulants.

❖ Coagulation is charge neutralization of finely divided and colloidal impurities in water into masses that can be filtered. In addition, particles have negative electrical charges, which cause them to repel each other and resist adhering together.

❖ Coagulation, therefore, involves neutralizing the negative charges and providing a nucleus for the suspended particles to adhere together. Flocculation is the bridging together of coagulated particles.

❖ Iron and aluminum salts such as ferric sulfate, ferric chloride, aluminum sulfate (alum), and sodium aluminate are the most common coagulants.

3. Chemical precipitation

❖ Chemical precipitation is a process in which chemical added reacts with dissolved minerals in the water to produce a relatively insoluble reaction product.

❖ Precipitation methods are used in reducing dissolved hardness, alkalinity, and silica. The most common example is lime-soda treatment.

4. Softening process

There are two types of softening process

1. lime soda process
2. zeolite process

Methods of lime soda softening

a) Lime soda process

❖ Lime-soda softening is classified as hot or cold, depending on the temperature of the water 80 °C and 150°CHot process softeners increase the rate of chemical reactions, increase silica reduction, and produce over-all better quality water.

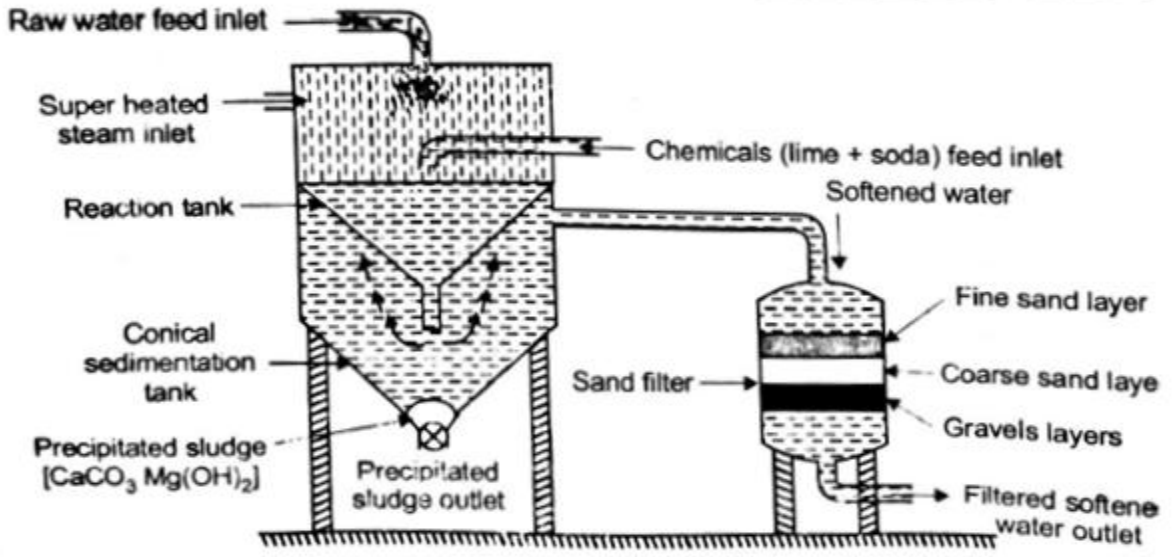
❖ Reaction tank in which the water is mixed thoroughly with chemical and steam.

❖ Conical sedimentation tank in which sludge settle down.

❖ Sand filter which ensures complete removal of sludge from the softened water.

❖ In the softening process, coagulants speed up settling of sludge by 25-50%.

❖ Sodium aluminate used as a coagulant in lime-soda softening being alkaline, also contributes to the softening reactions, particularly in reducing magnesium. Proper uses of coagulants help remove silica in the softening process.



Lime-Soda Process

Advantages of lime-soda softening

❖ The main advantage is that in reducing hardness, alkalinity, total dissolved solids, and silica are also reduced.

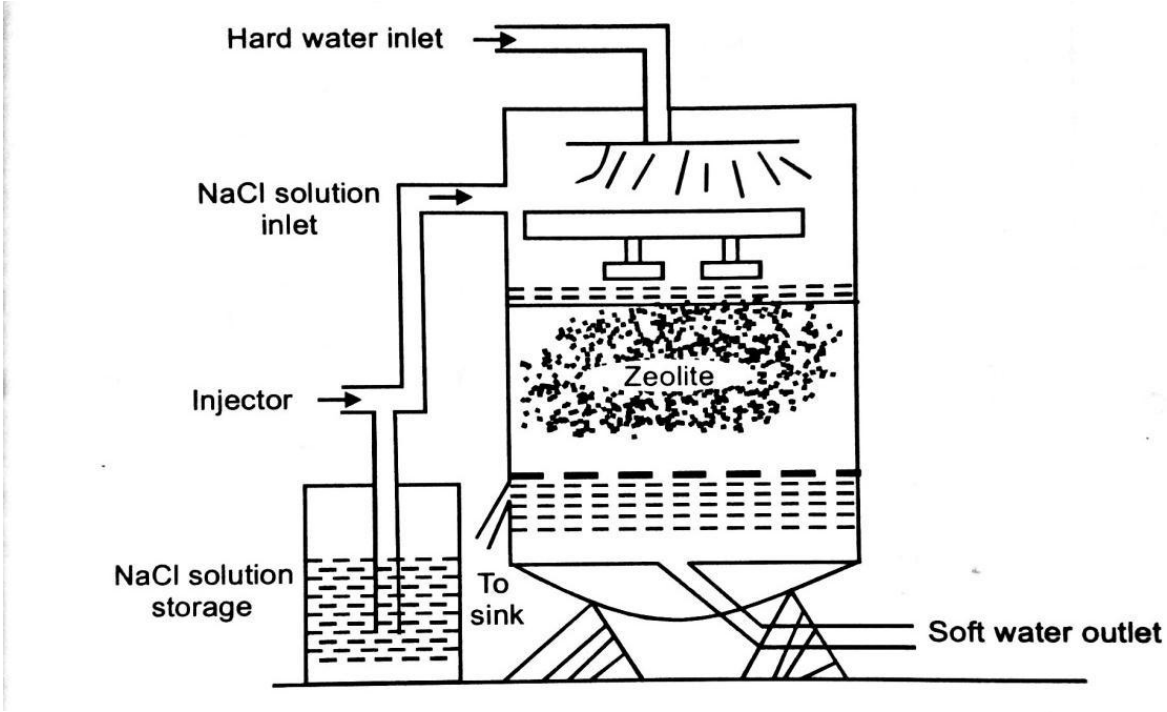
❖ With continuous hot process softening some removal of oxygen and carbon dioxide can be achieved

Disadvantages of lime-soda softening

- The main disadvantage is that while hardness is reduced it is not completely removed.

Zeolite process

- Zeolites are two types
  1. Natural Zeolites (Non porous)
  2. Synthetic Zeolites (porous)
- For softening of water by zeolite process hot water is percolated at a specified rate through a bed of zeolites and kept in a cylinder



$$Na_2Ze + Ca(HCO_3)_2 \rightarrow CaZe + 2NaHCO_3$$

$$Na_2Ze + Mg(HCO_3)_2 \rightarrow MgZe + 2NaHCO_3$$

$$Na_2Ze + CaCl_2(CaCO_3) \rightarrow CaZe + 2NaCl(Na_2SO_4)$$

$$Na_2Ze + MgCl_2(MagSO_4) \rightarrow MgZe + 2NaCl(Na_2SO_4)$$

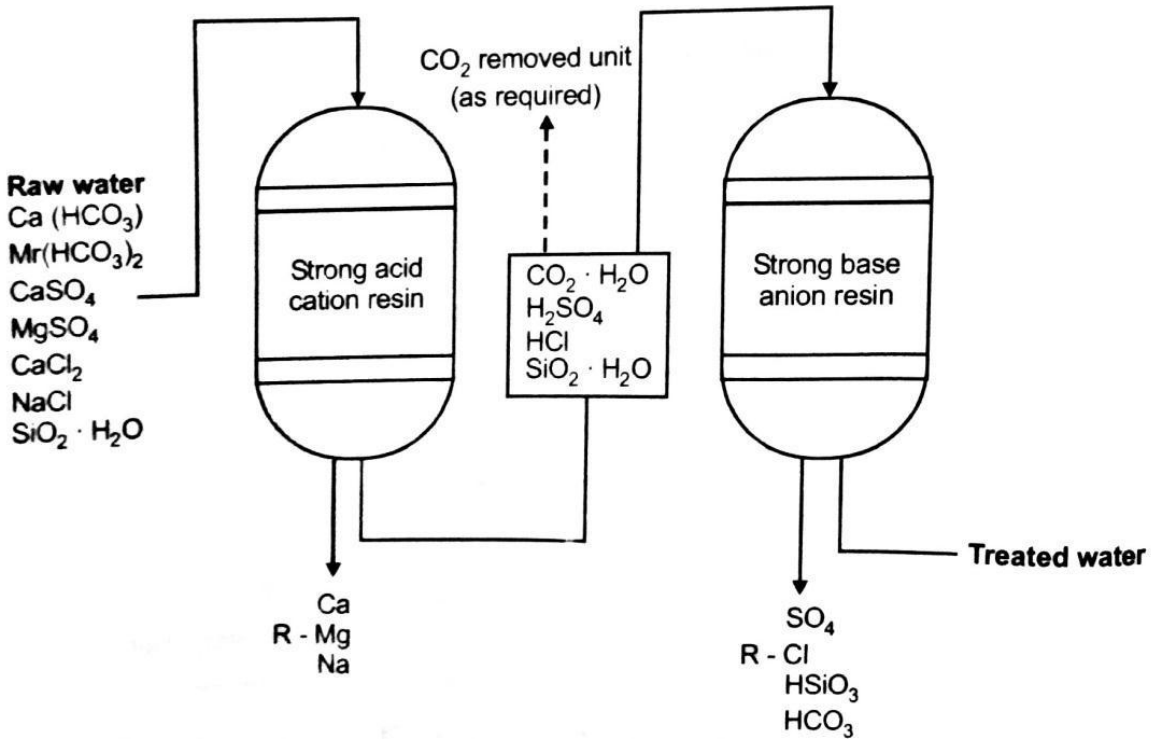
5. Ion Exchange

- Minerals dissolved in water form electrically charged particles called ions.

Ion exchange resins are two types: cation and anion

- Hard water is passed through the cation exchange bed which removes the cations like Ca+2 and Mg+2.And equal amount H+ ions are released from the bed to water.
- After cation exchange bed the hard water is passed through the anion exchange bed which removes the all Anion SO42- ,Cl- etc.. present in the water and equal amount of OH- ions are released from the bed to water.
- Thus the H+ and OH- ions get combined to produce water molecules
- Some synthetic and natural materials have the ability to remove mineral ions from water in exchange for others.
- For example, in passing water through a simple cation exchange softener all the calcium and magnesium ions are removed and replaced with sodium ions.

❖ Ion exchange resins usually are small porous beads that compose a bed several feet deep through which the water is passed.



Ion exchange

Ion exchange regeneration

❖ Ion exchange resins have a certain capacity for removing ions from water and when their capacity is used up they have to be regenerated. The regeneration is essentially reversing the ion exchange process.

❖ Cation exchangers operating on the sodium cycle, salt (NaCl) is added to replenish the sodium capacity. Resins operating on the hydrogen cycle are replenished by adding acid (H2SO4 or HCl).

❖ Anion exchangers are normally regenerated with caustic (NaOH) or ammonium hydroxide (NH4OH) to replenish the hydroxide ions.

Advantages of ion exchange

1. Ease of process control.
2. Variations of hardness in raw water do not have an adverse effect on the completeness of softening.
3. It takes up less space than the lime-soda system.
4. Produce better quality boiler at an economical cost.

Disadvantages of ion exchange

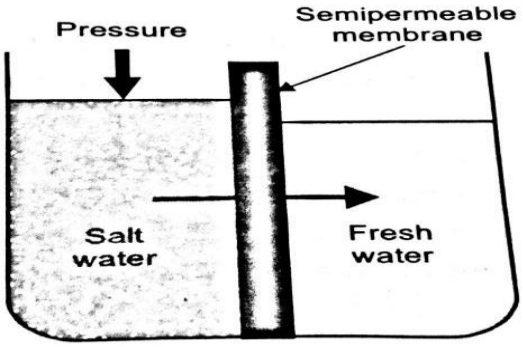
1. Sodium cycle ion exchange softening disadvantage is that the total solids, alkalinity, and silica contents of the raw water are not reduced.

Deaeration of water

1. Dissolved oxygen in water is a major cause of boiler system corrosion. It should be removed before the water is put in the boiler.
2. Feedwater deaeration removes oxygen by heating the water with steam in a deaerating heater.
3. Part of the steam is vented, carrying with it the bulk of the dissolved oxygen.

Reverse osmosis

- **Reverse Osmosis** uses a semi-permeable membrane that allows ions to pass from a more concentrated solution to a less concentrated solution without allowing the reverse to occur.
- Reverse osmosis overcomes the osmotic pressure with a higher artificial pressure to reverse the process and concentrate the dissolved solids on one side of the membrane.



Reverse osmosis

- Operating pressures of about 300 to 900 psi are required to achieve this.
- Reverse osmosis reduces the dissolved solids of the raw water, making

complete ready for further treatment. This process is suitable for any type of raw water,

Internal water treatment program

The purpose of an internal water treatment program is:

1. To react with incoming feed water hardness and prevent it from precipitating on the boiler metal as scale.
2. To condition any suspended matter such as hardness sludge in the boiler and make it non adherent to the boiler metal.
3. To provide antifoam protection to permit a reasonable concentration of dissolved and suspended solids in the boiler water without foaming.
4. To eliminate oxygen from the feed water.
5. To provide enough alkalinity to prevent boiler corrosion.
6. To prevent scaling and protect against corrosion in the steam-condensate systems.

Chemicals used in internal treatment

- Phosphates used to be the main conditioning chemical, but nowadays chelate and polymer type chemicals are mostly used. These new chemicals have the advantage over phosphates of maintaining scale-free metal surfaces.
- All internal treatment chemicals, whether phosphate, chelate, or polymer, condition the calcium and magnesium in the feed water. Chelates and polymers form soluble complexes with the hardness, whereas phosphates precipitate the hardness.

Internal treatment for hardness

1. At boiler operating temperatures, calcium carbonate in the feedwater breaks down to form calcium carbonate.
2. Sodium carbonate in the water partially breaks down to sodium hydroxide and carbon dioxide.
3. Internal treatment with phosphates transforms calcium bicarbonate to calcium phosphate and sodium carbonate.
4. In the presence of hydroxide alkalinity, magnesium bicarbonate precipitates as magnesium hydroxide or reacts with silica to form magnesium silicate.
5. These minerals are precipitated from solution in form of sludge,
6. . The conditioned sludge is then removed from the boiler by blow down.

7. When chelate is used for internal treatment, it reacts with calcium and magnesium salts to form soluble complexes. These complexes are in the form of dissolved solids and are removed by blow down.

Internal treatment for silica

1. If silica is present in the feed water, it tends to precipitate directly as scale at hot spots on the boiler metal and or combines with calcium forming a hard calcium silicate scale. In the internal treatment for silica, the boiler water alkalinity has to be kept high enough to hold the silica in solution.

2. Magnesium, present in most waters, precipitates some of the silica as sludge. Special organic materials or synthetic polymers are used to condition magnesium silicate from adhering to the boiler metal

Internal treatment for sludge conditioning

- Internal treatment for hardness results in insoluble precipitates in the boiler that form sludge.
- In addition, insoluble corrosion particulate (metal oxides) are transported to the boiler by condensate returns and from pre boiler feed water corrosion resulting in suspended solids.

Advantages

- Internal treatment is basically simple Scales or deposits, corrosion and carryover are minimized thereby improving efficiency and reducing energy consumption, preventing tube failures and unscheduled costly repairs, and reducing deposits, corrosion and contamination in the downstream equipments or processes.

16. Explain with a neat sketch the principle of any two classifiers ball mill (Nov/Dec 2013)

- Coal is pulverised to increase its surface exposure and complete combustion. This is done by using the pulverising mills

The different types of pulverising mills used for this purpose are

i) Ball mill
ii) Ball and race mill
iii) Impact and hammer mill
iv) Bowl mill

Ball and race mill

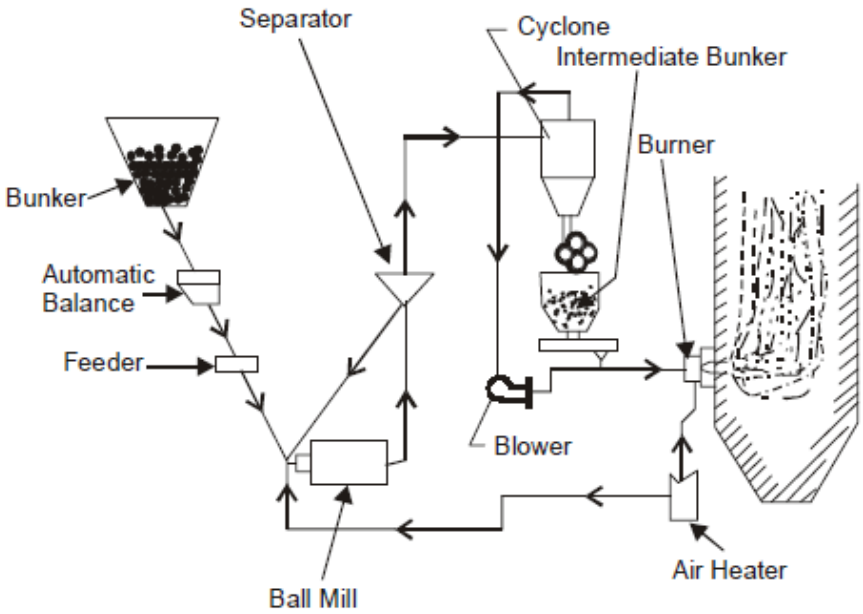


Figure16.1 line diagram of ball and race mill

- In this mill the coal passes between the rotating elements again and again until it has been pulverized to desired degree of fineness. The coal is crushed between two moving surfaces namely balls and races.
- The upper stationary race and lower rotating race driven by a worm and gear hold the balls between them. The raw coal supplied falls on the inner side of the races. The moving balls and races catch coal between them to crush it to a powder.
- The necessary force needed for crushing is applied with the help of springs. The hot air supplied picks up the coal dust as it flows between the balls and races, and then enters the classifier.
- Where oversized coal particles are returned for further grinding, where as the coal particles of required size are discharged from the top of classifier.

Impact or hammer mill

- Figure 16.2 below shows an impact mill in which pulverization is accomplished due to hammering action.
- The coal remains in suspension during the entire pulverizing process. The entire grinding element and the primary air fan are mounted on a single shaft

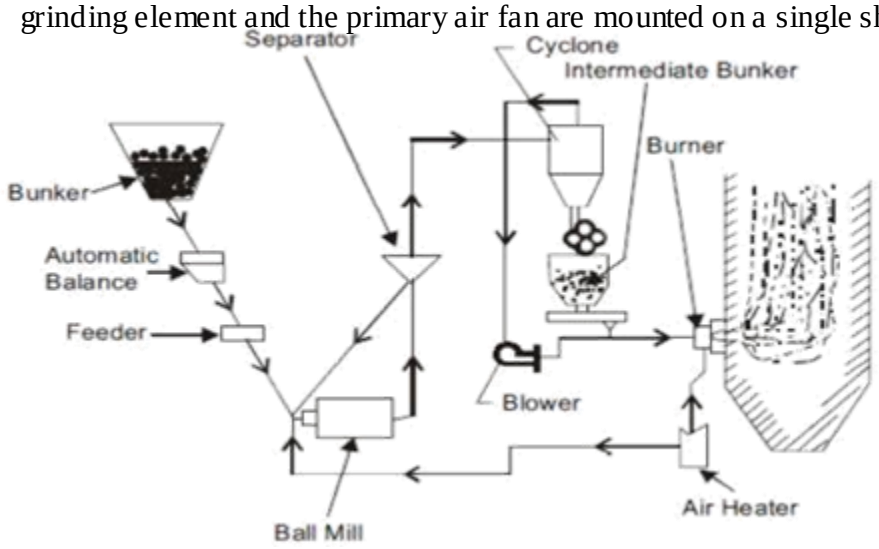


Fig 16.2 Hammer or impact mill

17. Explain in detail about pulverized coal firing. (Or) Explain the working of central bin system with a neat sketch. (Dec 2010, 11)(May/June 2012)

Pulverized coal firing is done by two systems:

(1) Unit System or Direct System.
(2) Bin or Central System.

1. Unit System or Direct System

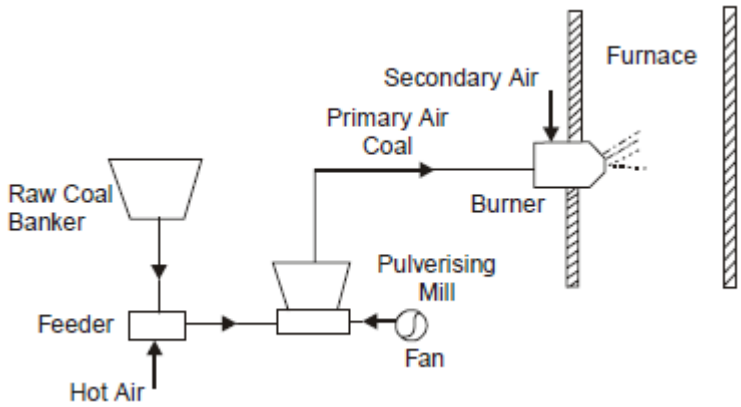


Fig 17.1 Unit System or Direct System

- In this system (Fig17.1) the raw coal from the coal bunker drops on to the feeder. Hot air is passed through coal in the feeder to dry the coal.

- ❖ The coal is then transferred to the pulverizing mill where it is pulverized.
- ❖ Primary air is supplied to the mill, by the fan.
- ❖ The mixture of pulverized coal and primary air then flows to burner where secondary air is added.
- ❖ The unit system is so called from the fact that each burner or a burner group and pulveriser constitutes a unit.

Advantage

1. The system is simple and cheaper than the central system.
2. There is direct control of combustion from the pulverizing mill.
3. Coal transportation system is simple.
4. It cheaper than central system
5. Maintenance charge is low.
6. No complex transportation.
7. Less space

Disadvantage

1. Flexibility is less.
2. In variable load no best

2.Bin or Central System:

- ❖ Crushed coal from the raw coal bunker is fed by gravity to a dryer where hot air is passed through the coal to dry it.
- ❖ The dryer may use waste flue gases, preheated air or bleeder steam as drying agent. The dry coal is then transferred to the pulverizing mill.
- ❖ The pulverized coal obtained is transferred to the pulverized coal bunker (bin).
- ❖ The transporting air is separated from the coal in the cyclone separator.
- ❖ The primary air is mixed with the coal at the feeder and the mixture is supplied to the burner

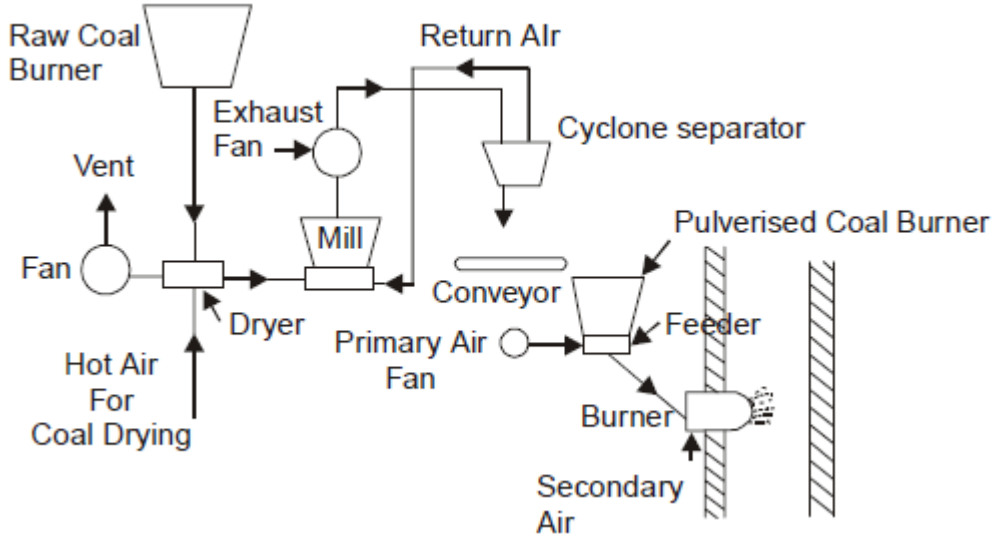


Fig 17.2 Bin or Central System

18. A steam power station has an installed capacity of 120 MW and a maximum demand of 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annual expenses on salary bill of staff and other overhead charges excluding cost of coal are Rs.50 × 105. The power station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4 × 105. If the rate of interest and depreciation is 10% determine the cost of generating per kWh? (NOV/DEC 2017)

Solution.

Maximum demand = 100 MW

Load factor = 0.5

Average load = $100 \times 0.5 = 50$ MW $= 50 \times 1000 = 50{,}000$ kW.
Energy produced per year = $50{,}000 \times 8760 = 438 \times 10^6$ kWh.
Coal consumption = $438 \times 106 \times (0.4/1000) = 1752 \times 10^6$ tonnes.

Annual Cost

(1) Cost of coal = $1752 \times 102 \times 80$ = Rs. $14{,}016 \times 10^2$
(2) Salaries = Rs. 50×10^5
(3) Interest and depreciation = $(10/100) \times 4 \times 10^5$ = Rs. 4×10^4
Total cost = Rs. $14{,}016 \times 10^3$ + Rs. 50×105 + Rs. 4×10^4
= Rs. $19{,}056 \times 10^3$

Cost of generation per kWh $= \frac{(19{,}056 \times 10^3)}{438 \times 10^6} \times 100$
= **4.35 paise.Ans.**

QUESTION BANK

PART-A

1. What is thermodynamic cycle? Or Explain basic thermodynamics cycles? (Nov/Dec14)(pg.no:01)
2. Comment on thermal efficiency of a steam power plant.(Dec 2012) (pg.no:03)
3. What is the Function of deaeration? (May/June 2012) (pg.no:03)
4. Define super heater: (Nov/Dec 2012) or What is the function of super heaters in a thermal plant?(may/june 15) (pg.no:04)
5. What are functions of a draught system? (May 2012) (pg.no:05)
6. What are functions of a draught system? (May 2012) (pg.no:05)
7. What are functions of a draught system? (May 2012) (pg.no:05)
8. How the combustion equipment for burning coal is classified? (May 2012) (pg.no:05)
9. What are the different types of draught system? (Nov 2011) (pg.no:05)
10. Mention the uses of fly ash. (May 2010) (pg.no:06)
11. What are the modern methods used in ash handling system? (APRIL/MAY 2010) (pg.no:07)
12. What is the mechanism of pulverised firing system? (Dec 08) (pg.no:07)
13. What are the different types of cooling tower? (Dec 09) (pg.no:07)
14. Write the use of water level indicator in a boiler? (Nov/Dec 2013) (pg.no:07)
15. What is function of hot primary air?(Nov/Dec 2013) (pg.no:08)
16. State the characteristics of good ash handling plant.(May 2011) (pg.no:08)
17. **What do you understand by the term boiler draught? (May 13) (Nov/Dec 2016)**
18. . Define fluidized bed combustion? (Nov/Dec 2010) (pg.no:08)
19. Describe the steps involved in the inplant handling of coal?(may/june 14) (pg.no:10)
20. State the characteristics of good ash handling plant.(May 2011) (pg.no:11)
21. What do you understand by the term boiler draught? (May 13) (pg.no:11)
22. What is meant by supercritical boilers?(Nov/dec 15) (pg.no:11)
23. What is pulveriser and why it is used?(Nov/dec 15) (pg.no:11)
24. **What is heat rate?Nov-Dec 2016**
25. **What is Steam Rate? Nov-Dec 2016**
26. **Define compounding of steam turbines?May-june 2017**
27. **What is stroker?classify it.May-June 2017.**

PART-B

1. Explain layout of thermal (or) Steam power plant. (Dec 2010, 11, May 10, 11) (Or) Draw the Rankin cycle for a coal fired and steam thermal power plant, State the means of increasing the efficiency of the plant.Nov-dec 2016)

2. Explain with a neat sketch the principle of any two classifiers ball mill (Nov/Dec 2013). (Refer page no: 18)

3. Explain in detail about pulverized coal firing. (Or) Explain the working of central bin system with a neat sketch. (Dec 2010, 11)(May/June 2012) (Refer page no: 19)

4. Pulverized coal burners: or Explain briefly about Pulverized coal burners? (Dec 2011)(May/June 2012) (Refer page no: 21)

5. With a neat sketch briefly explain about fluidized bed combustion.
(Dec 2011)(May/June2012) (Refer page no: 23)

6. **Explain in detail the coal handling system with suitable coal handing system or block diagram [Dec 2010] (or) Explain the various steps involved in "in plants coal" handling in thermal power.(or) Name the various equipment's used for transferring the coal. Explain the working of any one Equipment. (Dec 2011)(April/May 2011) (May-june 2017)**

7. What are the operations involved in ash handling system? (Nov/Dec 2010)(May/June 2012),(May-june 2017)

8. What is meant by high pressure boilers? Explain briefly about their types. **)(Nov-dec 2016)**

9. What is meant by super heater? Describe its classification(Refer page no: 40)

10. Explain with the aid of sketches of forced Draft System and induced draft system or what is the main function of draught system? (Nov/Dec 2010)(May/June 2012) **(May-june 2017)**

11. What is mean by steam condenser explain about briefer their cassation. (Refer page no: 43)

12. Explain in detail about hyperbolic cooling tower. (Or) How Cooling towers are are classified? Explain anyone with neat sketch (April/May2010) (Refer page no: 49)

13. Describe the Different types of over feed Stokers and discuss the merits and demerits of each over others (May 2013) (Refer page no: 53)

14.Write a short notes on co-generation system

15. Explain Binary Vapour Cycle?(Refer page no: 55)

16. Write a short notes on co-generation systems(Refer page no: 55)

PART-A

1. What are the main units in gas turbine power plants? (Anna Univ. Dec 2005)

The gas turbine plant consists of
(i)Compressor
(ii)Intercooler (iii)Regenerator
(iv)Combustion chamber
(v)Gas turbine
(vi)Reheating unit.

2. State any two application of gas turbine power plant? (APR/MAY 2018)

- It is used in jet, aircraft and ships.
- Stand by plants for hydro electric power plants.

3. What is the use of regenerator?.

- In the regenerator, the heat of the hot exhaust gases from the turbine is used to preheat the air entering the combustion chamber.

4. What is meant by reheating combustion chamber?

- Fuel is added to reheat the exhaust gases of high-pressure turbine. It is placed in between high pressure and low-pressure turbines.

5. State any two major advantages of gas turbine power plant.

(i)Smaller in size and initial cost is less.
(ii)It requires less water compared to steam power plant.

6. How the gas turbine blades are cooled? (Anna Univ. Dec 2008)

Film Cooling of Turbine Blades in Gas turbine is done by the principle of (i)Draw Cooling Air from Compressor
(ii)Injection of Coolant onto Blades Surface
(iii)Creation of an Insulating Sub layer
(iv)Lower the Effective Gas Temperature in the Boundary Layer.

7. Define mean effective pressure as applied to gas power cycles.How it is related to indicate power of an I.C. engine? (Anna Univ. April 1995 and 1996)

- Mean effective pressure is defined as the constant pressure acting on the piston during the working stroke. It is also defined a s the ratio of work done to the stroke volume or piston displacement volume.

Mean effective pressure,

Pm=Indicated power/ No. of working stroke x Stroke volume per second

8. Mention the various processes of the Brayton cycle (Anna Univ. Oct 1996),(May-June 2017)

(a)Isentropic compression
(b)Constant pressure heat supplied
(c)Isentropic expansion and
(d)Constant pressure heat rejection.

9. What are all the modification are carried out in Brayton cycle? Why?

In Brayton cycle, three modification can be carried out as follows.

(i)Regenerator

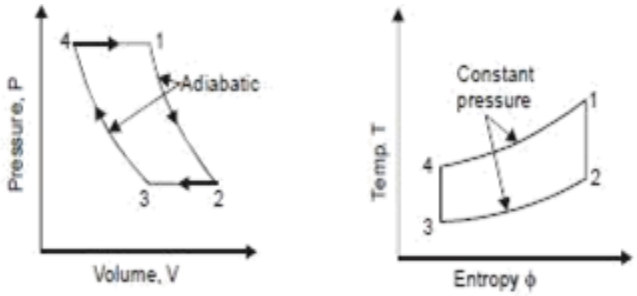
(ii)Reheater, and

(iii)Intercooler

10. Is it always useful to have a regenerator in a gas turbine power cycle? Why?

❖ It is not always useful to have a regenerator in a gas turbine cycle. Regenerator causes pressure drop of 0.035 to 0.2bar in compressed air and about 0.035bar in exhaust gases. These pressure drops affect to contain extend the gain in efficiency due to regeneration.

11. Draw the p-V and T-s diagram of Braytoncycle.Sketch the limited pressure cycle on p-V and T-s diagram and name various process.(Oct 2002,April 2000) (APR/MAY 2018)



12. What is the expression for optimum pressure ratio for maximum specific work out-put on Brayton cycle?.

Optimum pressure ratio $R_p=[T_3/T_1]^{2(\gamma-1)}$

13. In case of regenerative cycle, what are the factors affecting thermal efficiency of the cycle?

Maximum cycle temperature and pressure ratio.

14. What are the effects of introducing regeneration in the basic gas turbine cycle?

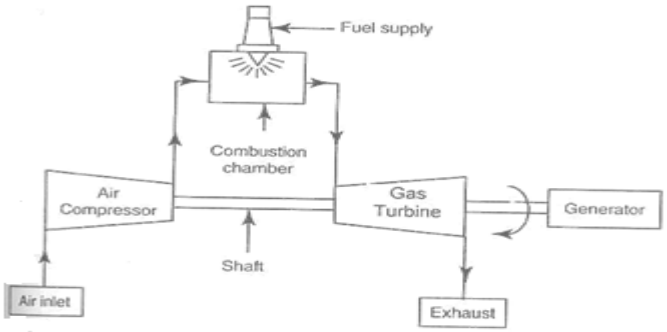
(i)The fuel economy is improved. The quantity of fuel required per unit mass of air is less.

(ii)The work output from turbine, work requires to the compressor will note changes.

(iii)Pressure drop will occur during regeneration.

(iv)It increase thermal efficiency when low pressure ratio.

15. Sketch the schematic arrangement of open cycle gas turbine plant and name the components.(Anna Univ. April 2004)



16. Why the gas turbine plants are generally designed for optimum pressure ratio for maximum specific work output?(NOV/DEC 2017)

❖ The gas turbine plants are generally designed for optimum pressure ratio for maximum specific work output because It results in the small plant and the efficiency curve is nearly flat in this region.

17. When will be the gas turbine cycle efficiency reaches maximum?

When pressure ratio, $R_p=1$ and is equal to $[T_3-T_1/T_3]$

18. When will the intercooler is provided between two compressors?

❖ When the pressure ratio is very high, then the intercooler is provided between compressors.

19. Discuss the effect of inter cooling in a gas turbine plant. (Anna Univ. June 2007)

(i)Heat supply is increased

(ii)It decreases the thermalefficiency

(iii)Work ratio will be increased (iv)Specific volume of air isreduced.

20. When the reheater is employed in the gas turbine cycle

❖ When the air-fuel ratio is high, the combustion products after expansion in the high-pressure turbine contain more oxygen. This, by introducing reheater the exhaust pressure can be reheated and expanded again in the low-pressure turbine.

21. What is the condition for maximum work in the case of reheater employed in the gas turbine cycle? (NOV/DEC 2018)

❖ For optimum work pressure ratio is equal for all the stages. i.e.

$R_{p1}=R_{p2}=.....=(R_p)^{1/n}$

R_P=pressure ratio, n-number of stages

22. What are the effects of reheat cycle?

(i)Thermal efficiency is less since the heat supplied is more.

(ii)Turbine output is increased for same expansion ratio.

23. What is the principal of operation of simple jet propulsion system? (Anna Univ. Nov 2003)

❖ What the works output of the gas turbine plants is used to produce high velocity jet of hot gases and this jet is used to propel the vehicles in which the systems are mounted such systems are kept as jet propulsion systems.

24. Why is the maximum cycle temperature of gas turbine plant much lower than that of diesel power plants? (Anna Univ. June 2009)

❖ Air alone is combusted in gas turbine plant instead of air-diesel combustion in the diesel power plant.

25. List out the inherent advantages of the combined power cycles. (Anna Univ. June 2007)

(i)The efficiency of the combined cycle plants is better than simple gas turbine cycle.

(ii)The capital cost of combined plant per kW output with supplementary firing is slightly higher than a simple gas turbine plant.

(iii)The combined plant is more suitable for rapid start and shutdown.

(iv)The cooling water requirement of a combined cycle is much lower than a pure steam plant

having same output.

(v)The combined system offers self-sustaining feature. If power station is down due to some fault, the gas turbine offers to start the station from cold condition. No outside power source is required.

(vi) It gives high ratio of power output to occupy ground space.

(vii)The environmental standards of many old fossil fuel plants are not acceptable and they are likely to be closed. These can be renovated by replacing the old boiler with the gas turbine unit and heat recovery boiler.

(viii)It provides more flexibility of operation due to multiple units.

(ix) Low operating manpower.

(x) Less down time for maintenance.

(xi)Combined cycle power plant minimizes the visual impact on environment.

26.What are the essential components of a diesel power plant?

1. Engine
2. Air intake system
3. Exhaust system
4. Fuel system
5. Cooling system
6. Lubrication system
7. Engine starting system
8. Governing system

27. What are the applications of diesel power plant?

1. Peak load plant
2. Mobile plants
3. Stand by units
4. Emergency plant
5. Starting station
6. Nursery station

28. What are the commonly used fuel injection systems in a diesel power station?

1. Common rail injection system.
2. Individual pump injection system.
3. Distribution system

29. What are the methods of cooling in a diesel engine power plant?

1. Thermo-system cooling
2. Forced or pump cooling
3. Pressurised cooling
4. Evaporative cooling
5. Cooling with thermostatic regulator.

30. What are the methods of starting systems in large and medium size engines?

1. Starting by an auxiliary engine.
2. Use of electric motors or self starters.
3. Compressed air systems.

31. What are the methods of lubrication systems in I.C. engines?

1. Wet sump lubrication
2. Dry sump lubrication
3. Mist lubrication system

32. What are the methods of cooling the engine?

1. Air cooling
2. Water cooling

33. What are the different types of governing system in I.C. engines?

1. Hit and Miss government engine
2. Quality governed engine
3. Quantity governed engine.

34. What are the performance parameters in I.C. engines?

1. Power and Mechanical efficiency
2. Mean effective pressure and torque.
3. Specific output
4. Volumetric efficiency
5. Fuel-air ratio
6. Specific weight
7. Specific fuel consumption
8. Thermal efficiency and heat balance.

35.What are all the application of the diesel power plant? (Anna Univ. June 2007, Dec 2008 and April/May 2010),(April/May 2017).

1.It is quite suitable for mobile power generation

2.It can be used as peak load plants in combined with thermal or hydro plants. 3.It can be used as stand by plants for emergency service.

36.State the merits and demerits of closed cycle gas turbine over open cycle gas turbine power plant.(April/May 2010)

Merits:

- Efficiency is same through the cycle
- The turbine blades do not wear away, since the combustion is external
- Starting of the plant is easy
- Low quality fuels can be used since the combustion is external
- Thermal stresses are low
- No need for internal cleanings

Demerits:

- Separate pre-cooler arrangement is necessary
- The size and weight are more
- Initial cost and maintenance cost are more
- Combustion efficiency is less
- Coolant is required for pre-cooler, therefore, it is used for stationary applications such as power generation etc.,
- The response to load variation is less

37.State the fuels used in the gas turbine power plant(April/May 2011)

❖ Residual liquid fuels, residue left after the profitable light fraction have been extracted from the crud, have been used in gas turbine to some extend.

38. What is mean by combined cycle power plant? (April/May2011)

❖ The maximum steam temperature in power cycle exceeds $600^{O}C$, but the pulverized coal furnace temperature is about $1300^{O}C$. So, there is lot of energy wasted in the power plant. To increase the efficiency and reduce the fuel, the combined power cycles are introduced by superposing a high temperature power plant as a topping unit to the steam plant.

39.List the a fuel differences between the closed cycle and open cycle gas turbine power plant.(Nov/Dec 2011)

Advantages for open cycle gas turbine:

- ❖ No pre cooler is required because of burned gas from gas turbine exhausted to atmosphere
- ❖ For the same power developed the size and weight of the open cycle gas turbine unit are less
- ❖ Initial cost and maintenance cost of the plant are less
- ❖ Combustion efficiency is more
- ❖ Coolant is not required, therefore, it is used for moving vehicle such as aircraft, jet propulsion etc.,

Disadvantages for closed cycle gas turbine:

- ❖ Separate precooler arrangement is necessary
- ❖ The size and weight are more
- ❖ Initial cost and maintenance cost are more
- ❖ efficiency is less

40. What are the functions of lubrication system? (Nov/Dec 2011)

(i)Supplying clean lubricating oil with certain viscidity to friction parts, keeping the liquid friction between two parts moved face to face, avoiding dry friction, reducing abrasion and abasing the power consumed by friction.

(ii)Taking away the heat and metal scraps bring by frictions

41.What are the methods by which the efficiency of an open cycle gas plant can be improved? (April/May 2012)

(i)Regenerator
(ii)Intercooler
(iii)Reheater

42. What is meant by regeneration? (April/May 2012)(Nov/Dec 2016)

❖ The temperature of the exhaust gases of the turbine is higher than the temperature of the air after compression. If the heat energy is used to heat the air after compression in the heat exchanger called "regeneration". It will reduce the energy requirement from the fuel thereby increasing the efficiency of the cycle.

43.What are the methods by which thermal efficiency of a gas turbined power plant be improved? (Nov/Dec 2012)

(i)Regenerator
(ii)Intercooling
(iii)Reheating
(iv)Combination of intercooling, reheating and regenerator

44.What is the basic difference between a diesel engine and a steam turbined? (Nov/Dec 2012)

❖ The basic difference is that diesel engine is the internal combustion(IC) engine where as steam turbine is external combustion engine.

45.What you meant by regeneration in gas turbine power plant (May/June 2013),(Nov/Dec 2016)

❖ The partial bleeding of steam from the turbine to pre-heat the air to reduce the fuel consumption and to increase the efficiency is called regeneration.

46. How the soild injection system is classified? (May/June 2013)

1.Individual pump and nozzle system
2.Unit injector system
3.Commonrail system
4.Distributor system

47.Write the classification of gas turbine? (Nov/Dec 2013),(Nov/Dec 2016)

Classification of gas turbines

1.According to the cycle of operation
   a.Open cycle gas turbines b.Closed cycle gas turbines, and c.Semiclosed cycle gas turbines
2.According to the process
   a.Constant pressure gas turbines, and
   b.Constant volume gas turbines
3.According to the use
   a.Industrial gas turbines, and
   b.Air craft gas turbines
4.According to the type of load
   a.Peak load
   b.Stand by
   c.Base load
5.According to the application
   a.Air craft
   b.Marine
   c.Locomotive
   d.Transport
6. According to the type of fuel
   a.liquid
   b.Gas
   c.Solid

48. Write two advantages of diesel poweplants?(Nov/Dec 2013)

1. Diesel power plants are cheaper.
2. It occupies less space.

49.Name two combined power cycle?

❖ Combined cycle of gas turbine and steam power plant
❖ Combined cycle of gas turbine and the diesel power plant.

50.Difference between otto cycle and diesel cycle?(Nov/dec 15)

Otto cycle	Diesel cycle
Heat transfer at constant **VOLUME**	Heat transfer at constant **PRESSURE**
The combustion is initiated using a spark plug	Auto-ignition due to compression
In the Otto cycle air and fuel are introduced together.	In the Diesel cycle the fuel and air are introduced in deferent steps of the cycle

51.Why power generation by gas turbine is more attractive than other turbine?(Nov/dec 15)

❖ The gas turbine power generation is preferred over other turbine because of the following advantages:

1.Less space is required

2.poor qualities and wide variety of fuels can be used.

3.plant can be quickly started and pickup load and hence mostly preferred as peak load plant

4.low weight and less initial cost.

5.Neligible vibration so heavy foundation and buildings is not required

PART-B

1.Explain the various power plant cycles or Draw and explain PV and TS diagram of brayton cycle.(Nov/dec 15)(Nov/Dec 2016)

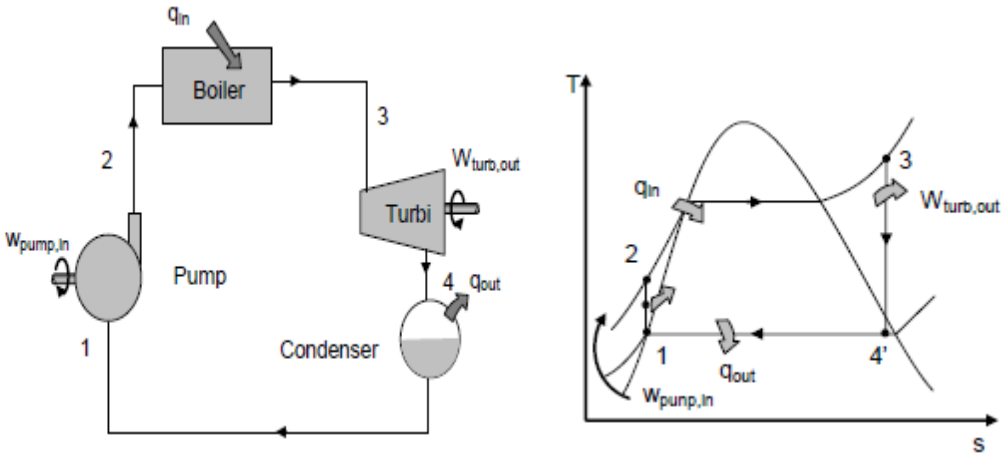
Power plants cycle generally divided in to the following groups,

(1) Vapour Power Cycle(Carnot cycle, Rankine cycle, Regenerative cycle, Reheat cycle, Binary vapour cycle)

(2) Gas Power Cycles(Otto cycle, Diesel cycle, Dual combustion cycle, Gas turbine cycle.)

Rankinecycle :

- This cycle is an ideal cycle which is used for comparing the performance of steam power plants.



Process 1 – 2:

- In this process water is converted into steam isothermally and is basically (i.e) T = constant and P = constant.
- At point 1, the working fluid is existing as a water and point 2 the working fluid converted into steam.

Process 2 – 3:

- The dry saturated steam expands is tropically in the turbine for developing mechanical work.
- Pressure falls from $P_2 to P_3$ and temperature $T_2 to T_3$. Therefore it is converted into dry steam to wet steam.

Process 3 – 4:

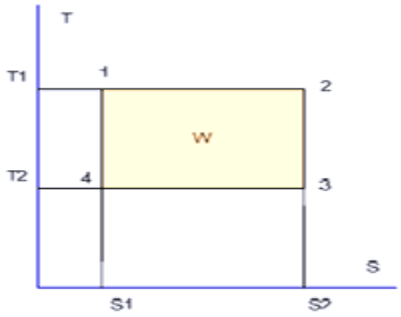
- The wet steam is then condensed in a condenser isothermally and is basically. Then wet steam is converted to water is condenser.
- This process is a heat rejection process; heat is rejected from wet steam to atmosphere.

Process 4 -1:

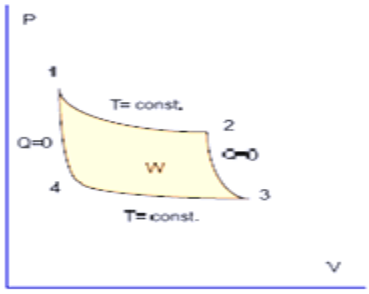
- The water is heated at constant volume process from $T_4 to T_1$ and pressure is also $\uparrow es$. From $P_4 to P_1$. During this process heat is added for heating.

Carnot cycle:

It is also called as constant temperature cycle.



T-S Diagram



P-V Diagram

Process 1 – 2: P and T ↑ *es* and volume ↓ *es*. No addition or rejection of heat is this process.

Process 2 – 3: Heat is supplied at constant. Temperature to working fluid.

Process 3 – 4: Pressure is temperature decreases.

Process 4 – 1: Heat is rejected is thermally and fluid attains its initial position.

- ❖ This cycle is of great value to heat power theory although it has not been possible to construct a practical plant on this cycle. It has high thermodynamics efficiency.
- ❖ It is a standard of comparison for all other cycles. The thermal efficiency (η) of Carnot cycle is as follows:

$$\eta = (T1 - T2)/T1$$

where, T1 = Temperature of heat source

T2 = Temperature of receiver

OTTO CYCLE

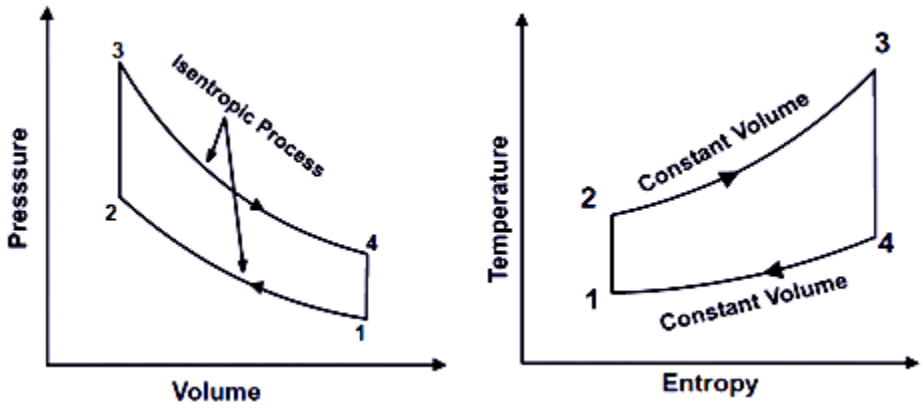
- ❖ Otto cycle is the idealized cycle for the spark-ignition internal combustion engines.
- ❖ This cycle is shown above on p-v and T-s diagrams. The Otto cycle 1-2-3-4 consists of following four process:

Process 1-2: Reversible adiabatic compression of air.

Process 2-3: Heat addition at constant volume.

Process 3-4: Reversible adiabatic expansion of air.

Process 4-1: Heat rejection at constant volume.



Compression ratio

From previous definition, compression ratio = $r_v = \frac{V_1}{V_2} = \frac{V_4}{V_3}$

Since fixed mass:

$$r_v = \frac{v_1}{v_2} = \frac{v_4}{v_3}$$

1-2 Isentropic compression

Applying First law:

U_2-U_1 = Q - Win

Q = 0 (since, reversible adiabatic compression)

Win = U_2-U_1

$$\frac{v_2}{v_1} = \frac{1}{r_v}$$

$$R = \frac{P_2 v_2}{T_2} = \frac{P_1 V_1}{T_1}$$

$$= \frac{P_2}{P_1} = \frac{T_2}{T_1}\frac{V_1}{V_2}$$

2-3 Constant volume heat addition

Applying First law:

U3-U2 = +Qin - W

W = 0 (since, it is a constant volume process)

Qin = U3-U2

$$v = \frac{P_2}{RT_2} = \frac{P_3}{RT_3} \Rightarrow \frac{P_3}{P_2} = \frac{T_3}{T_2}$$

3-4 Isentropic Expansion

Applying First law:

U_4-U_3 = Q - Wout

Q = 0 (rev. adiabatic expansion)

$W_{out} = U_4-U_3$

$$\frac{P_4V_4}{T_2} = \frac{P_3V_3}{T_3} =. \frac{P_4}{P_3} = \frac{T_4}{T_3}\frac{V_3}{V_4}$$

$$\frac{V_4}{V_3} = r_v$$

4-1 Constant volume heat removal

Applying First law:

U_1-U_4 = - Qout + W

W = 0 (no piston work)

Qout = U_4-U_1

$$V=\frac{P_4}{RT_2} = \frac{P_1}{RT_1}$$

$$\frac{P_4}{P_1} = \frac{T_4}{T_1}$$

Otto cycle thermal efficiency

The thermal efficiency is given by:

$$\eta_{cycle} = \frac{w_{net}}{Q_{in}}$$

$$=\frac{w_{out} - w_{in}}{Q_{in}}$$

$$= \frac{(U_3-U_4)-(U_2-U_1)}{(U_3-U_2)}$$

$$\eta_{cycle} = \frac{(U_3-U_2)-(U_4-U_1)}{(U_3-U_2)}$$

$$=1-\frac{(U_4-U_1)}{(U_3-U_2)}$$

The specific heats are assumed to be constant.

$$1 \rightarrow 2 \quad \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1} = r_v^{\gamma-1}$$

$$3 \rightarrow 4 \quad \frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1} = \left(\frac{1}{r_v}\right)^{\gamma-1}$$

Here y=1.4 at ambient temperature

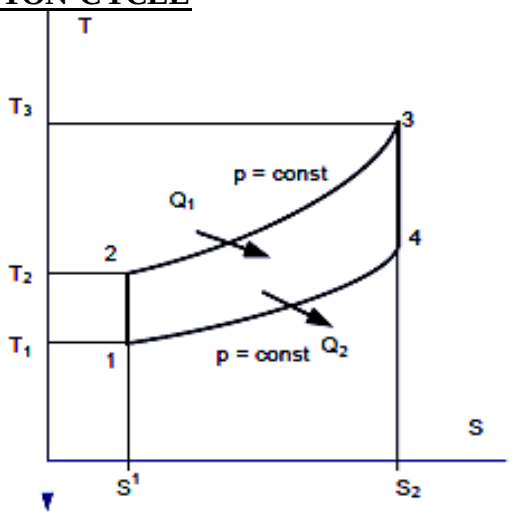
$$\eta_{Otto} = 1 - \frac{(U_4 - U_1)}{(U_3 - U_2)} = 1\text{-}\frac{m C_v (T_4 - T_1)}{m C_v (T_3 - T_2)}$$

$$\eta_{Otto} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} = 1\text{-}\frac{T_1\left(\frac{T_4}{T_1} - 1\right)}{T_2\left(\frac{T_3}{T_2} - 1\right)}$$

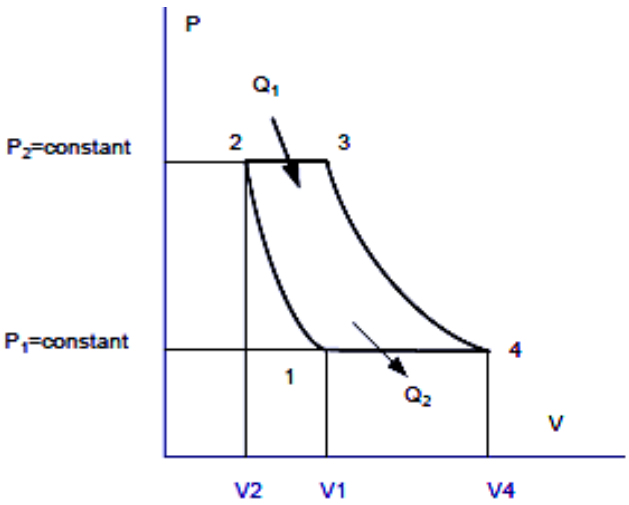
but $r_v = \frac{T_2}{T_1} = \frac{T_3}{T_4} = \frac{T_4}{T_1} = \frac{T_3}{T_2}$

$$\eta_{Otto} = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{r_V{}^{\gamma-1}}$$

BRAYTON CYCLE



T-S Diagram



P-V Diagram

The brayton cycle 1-2-3-4 consists of following four process:

a)Isentropic compression

(b)Constant pressure heat supplied

(c) Isentropic expansion and

(d)Constant pressure heat rejection.

Thermal efficiency:

The thermal efficiency of the ideal Brayton cycle is

$$\eta = 1 - \frac{Q_C}{Q_H}$$

$$\eta = 1 - \frac{m C_r (T_4 - T_1)}{m C_r (T_3 - T_2)}$$

$$\eta = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

Since processes 1-2 & 3-4 are isentropic between the same pressures :-

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_3}{T_4} = r_p^{\frac{\gamma-1}{\gamma}}$$

Where r_v is the pressure ratio

$$\frac{P_2}{P_1} = \frac{P_3}{P_4}$$

$$T_3 = T_4 r_p^{\frac{\gamma-1}{\gamma}} \text{ and } T_2 = T_1 r_p^{\frac{\gamma-1}{\gamma}}$$

$$T_3 - T_2 = (T_4 - T_1) r_p^{\frac{\gamma-1}{\gamma}}$$

Hence, substituting in the efficiency expression

$$\eta = 1 - \frac{1}{r_p^{\frac{\gamma-1}{\gamma}}}$$

This is the efficiency for ideal Joule/Brayton Cycle.

Work Ratio

It may easily be shown from the expression,

Work ratio $= \frac{mC_p(T_3-T_4)-mC_p(T_2-T_1)}{mC_P(T_3-T_4)}$

And a similar approach to that above, that work ratio $=1-\frac{T_1}{T_3}r_p^{\frac{\gamma-1}{\gamma}}$

2. Discuss briefly the methods employed for improvement of thermal efficiency of open gas turbine power plant (April/May 2010)(or)Write detailed technical notes on the following i)Regeneration ii)Reheating (April/May 2011) (May/June 2013),(Nov-Dec 2016),(May-june 2017)

1.Gas turbine cycle with regeneration

- The temperature of the exhaust gases of the turbine is higher than the temperature of the air after compression if the heat energy is used to heat the air after compression in the heat exchanger called "regeneration".
- It will reduce the energy requirement from the fuel there by increasing the efficiency of the cycle.
- Fig1. (a) shows the single stage regenerative gas turbine cycle and Fig1. (b) is the corresponding cycle represented on T-s diagram.

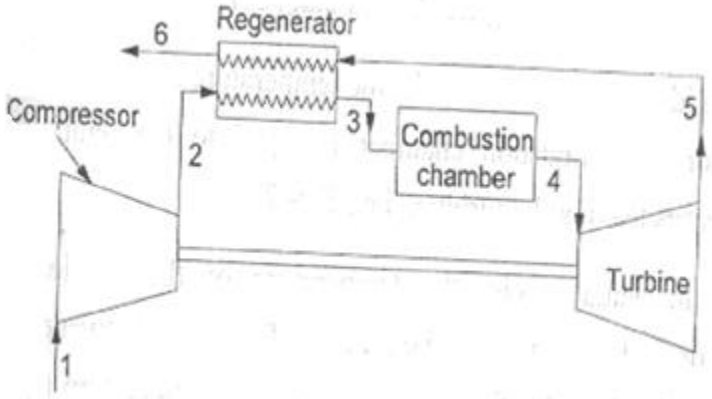


Fig-1(a) Gas turbine cycle with regeneration

- Air is drawn from the atmosphere into the compressor and is compressed isentropically to state to.It is then heated at constant pressure in the regenerator to state 3 by the exhaust gases from the turbine.
- Since the temperature of the air is increased before it reaches the combustion chamber, less amount of fuel will be required to attain the designed turbine inlet temperature of the products of combustion.
- After combustion at constant pressure in the combustion chamber, the gas enters the turbine at state 4 and expands to 5.
- It then enters the regenerator as stated earlier, where it gives up a portion of heat energy to the compressed air from the compressor and leaves the regenerator at state 6.

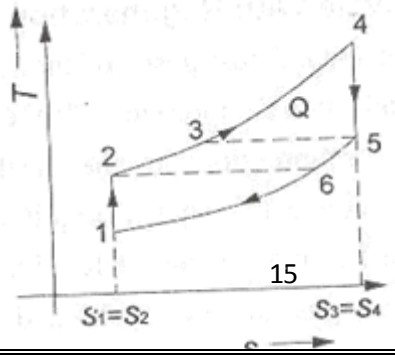


Fig-1(b) T-S diagram

- In an ideal regenerative cycle, the temperature of the air leaving the regenerator to combustion chamber is equal to the temperature of exhaust gases leaving the turbine. i.e. $T_3=T_5$.
- But in actual cycle, a temperature of the air leaving the regenerator is given by the ratio of the actual temperature rise to the maximum possible rise.

Effectiveness, $=T_3-T_2/T_5-T_6=T_3-T_2/T_5-T_2$ $(T_2=T_6)$

- For regenerative cycle, for unit mass flow rate

Heat supplied, $Q_s = C_p(T_4-T_3)$

- (For process 2-3, heat is supplied by regenerator)

Heat rejected, $Q_R=C_P(T_6-T_1)$

- (For process 5-6, heat is rejected by regenerator)

Turbine work, $W_T=C_P(T_4-T_5)$

Compressor work, $W_C=C_P(T_2-T_1)$

Efficiency = $1-\frac{Q_R}{Q_S}=1-\frac{T_6-T_1}{T_4-T_3}$

For ideal cycle $T_3=T_5, T_6=T_2$

$\eta = 1-\frac{T_2-T_1}{T_4-T_5}=1-\frac{T_1\left[\frac{T_2}{T_1}-1\right]}{T_4\left[1-\frac{T_5}{T_4}\right]}$

we know that ,$\frac{T_2}{T_1}=\left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$ and

$\frac{T_5}{T_4}=\left[\frac{P_3}{P_4}\right]^{\frac{\gamma-1}{\gamma}}=\left[\frac{P_1}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$ $[\,here P_5=P_1, P_4=P_3=P_2\,]$

$$\eta = 1 - \frac{T_1\left[\left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}} - 1\right]}{T_4\left[1 - \left[\frac{P_1}{P_2}\right]^{\frac{\gamma-1}{\gamma}}\right]}$$

$$\eta = 1 - \frac{T_1}{T_4}\frac{\left[P_2^{\frac{\gamma-1}{\gamma}} - P_1^{\frac{\gamma-1}{\gamma}}\right]/P_1^{\frac{\gamma-1}{\gamma}}}{\left[P_2^{\frac{\gamma-1}{\gamma}} - P_1^{\frac{\gamma-1}{\gamma}}\right]/P_2^{\frac{\gamma-1}{\gamma}}}$$

Efficiency of the regenerative Brayton cycle,

$$\eta = 1 - \frac{T_1}{T_4}\left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\eta = 1 - \frac{T_1}{T_4}\left[R_P\right]^{\frac{\gamma-1}{\gamma}}$$

❖ From the above formula, it is obvious that the efficiency of the regenerative Brayton cycle depends not only on the pressure ratio but also on the ratio of the extreme temperatures.

3.Gas turbine Cycle with inter cooling

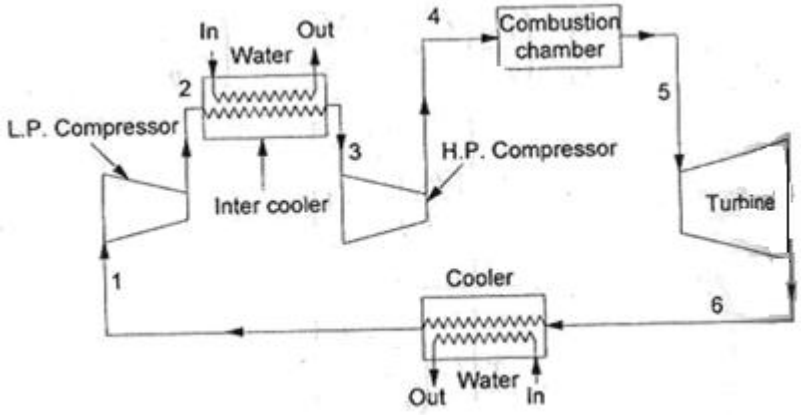


Fig-3(a)-Gas turbine cycle with intercooler.

❖ The thermal efficiency of the Brayton cycle may further be increased by providing multistage compression with intercooler between the compressors and multistage expansion with reheater between the turbines.

❖ The work required during multistage compression with intercoolers is less than the single stage compression.

❖ Similarly, the work output from the turbine is increased by multistage expansion with reheating.

❖ As a result, the network output from the plant increases. Fig 2 shows an ideal gas turbine plant operated by Brayton cycle with two-stage compression.

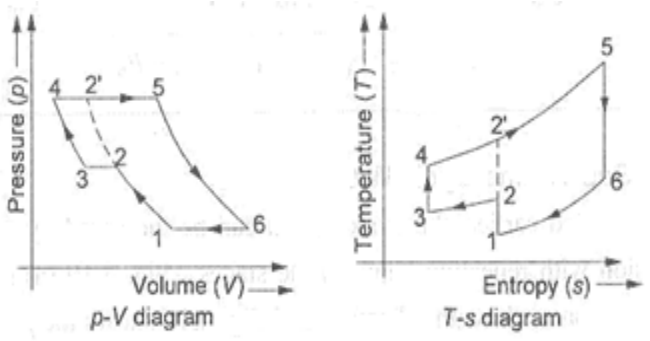


Fig-2(b) - p-V and T-s diagram

4. Gas turbine cycle with Reheater

❖ As stated earlier, the work output can be increased by multistage expansion with reheating between the stages.

❖ Fig 4 shows the ideal Brayton cycle with reheating and fig5 shows the p-V and T-s diagram for the same.

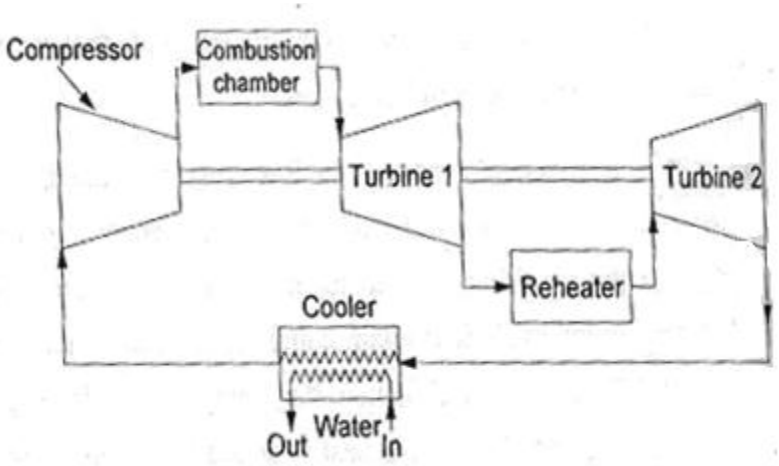


Fig 4-Gas turbine cycle with reheater

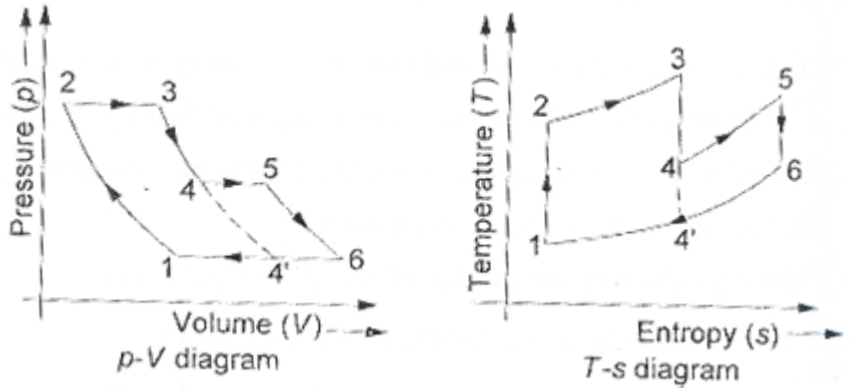


Fig-5-p-V and T-s diagram

- The air is first compressed in the compressor, passed into the heating champer, and then to the first turbine.
- The air is once again passed into the heating champer called **reheater** and then the 2nd turbine.
- The area under p-V diagram is increased by the amount 4'-4-5-6-4'. Therefore, the network is increased.
- In Fig5, the ideal cycle without reheater is shown by the process 1-2-3-4'-1, and the cycle with reheater is shown by 1-2-3-4-5-6-1. Work done required by the compressor per kg of air

$$W_C=C_P(T_2-T_1)$$

- Work done by 2 turbines per kg of air $W_T=C_P(T_3-T_4)+C_P(T_5-T_6)$

Network, $W=W_T-W$

5. Gas turbine Cycle with intercooling, Reheating and Regeneration

- The previously stated 3 methods for improving thermal efficiency of the cycle are combined together for getting maximum efficiency.
- Fig6 shows the ideal Brayton cycle with intercooling, reheating and regeneration and Fig7 shows the same processes in T-s diagram
- Work required by the compresors $W_C=C_P(T_2-T_1)+C_P(T_4-T_3)$
- Work done by the turbine $W_T=C_P(T_6-T_7)+C_P(T_8-T_9)$

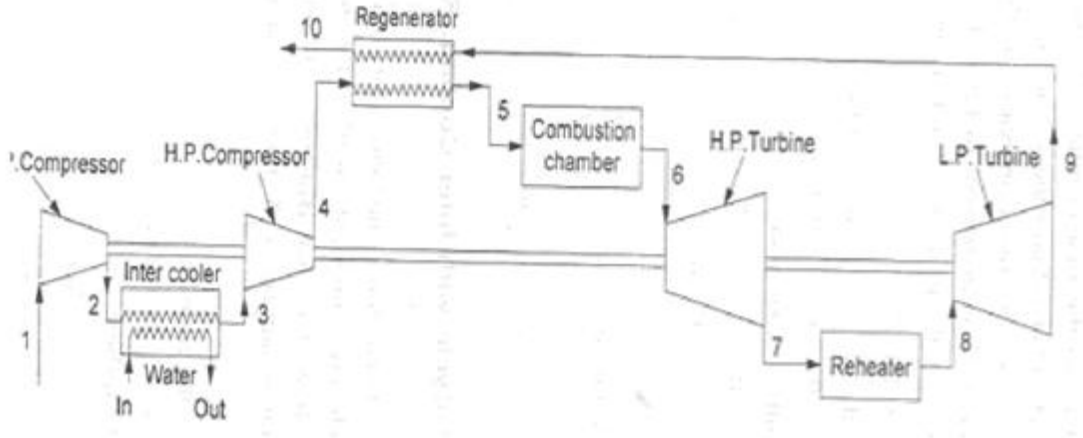


Fig-6-Brayton cycle with inter cooler, reheater and regeneration

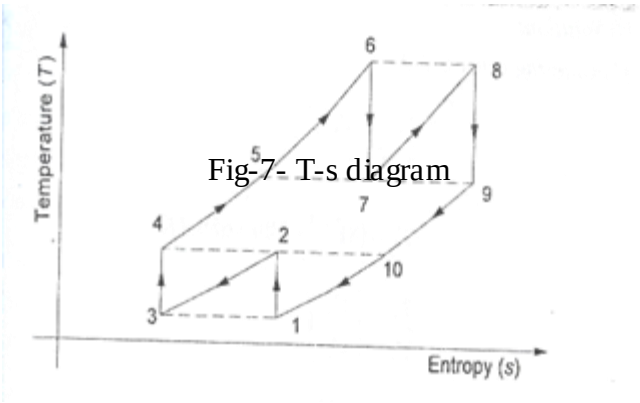


Fig-7- T-s diagram

Network, $W=W_T-W_C$

Heat supplied externally to the cycle

$Q_s=C_p(T_6-T_5)+C_p(T_8-T_7)$

Heat rejected, $_{QR}=C_p(T_{10}-T_1)+C_p(T_2-T_3)$

Thermal efficiency of the cycle

Therefore $=1-Q_R/Q_s=1-((T_6-T_5)+(T_8-T_7)/(T_{10}-T_1)+(T_2-T_3))$

3. List the essential components of diesel power plants and explain them briefly? (April/May 2010)Or With a neat sketch explain in detail, about the component and layout of diesel engine power plant (April/May 2011)Or List the various components of diesel engine power plant and explain its functions with neat sketch (Nov/Dec 2011)(Nov/Dec 2016)

Components of diesel power plants

The essential components of diesel electric power plant are

- ❖ Engine
- ❖ Air intake system
- ❖ Engine starting system
- ❖ Fuel system
- ❖ Exhaust system
- ❖ Cooling system
- ❖ Lubricating system

1,Engine

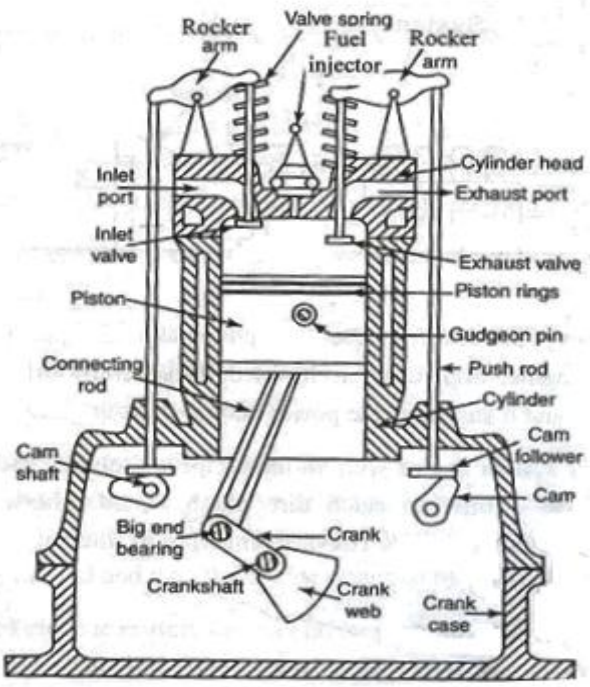


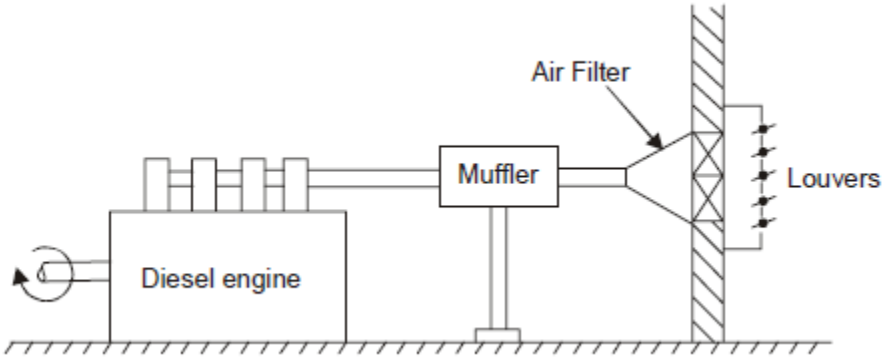
Fig-8- General view of diesel engine

❖ Engine is the main component of the plant which develops required power. This is the main component of a diesel power plant. The parts of the engine are shown in fig8.

❖ The engines are classified into two-stroke engine and four-stroke engines. Engine is generally directly coupled to the generator for developing power. In diesel engines, air admitted into the cylinder is compressed, that compression ratio being 12-20.

❖ At the end of the compression stroke, fuel is injected. The fuel is burned and the burning gases expand and do work and the piston. The shaft of the engine is directly coupled to the generator. After the combustion the burned gases are exhausted to the atmosphere.

3.Air intake system



❖ It removes the dust from the atmospheric air and supplies the fresh air to the engine. Super charger,

if fitted, is generally driven by the engine itself and it augments the power output of the engine.

❖ The air system begins with and intake located outside the building provided with a filter to catch dirt which would otherwise cause excessive wear in the engine. The different types of filters used in the air intake system are

1.Dry or oil bath filter

2.Oil impingement type of filter

❖ The following precautions that should be taken while constructing air intake system.

1. Air intakes should not be located inside the engine room.
2. The air-intake line used should neither have too small a diameter nor too long
3. Airt should not be taken from a confined space
4. Air intake filters should not be located in an in accessible location

Air filter and super charger

❖ The air filter is used to remove the dust from the air which is taken by the engine. The function of the super charger is to increase the pressure of the air supplied tothe engine and there by increasing the power of the engine.

3. Engine Starting System

❖ This system includes air compressor and starting air tank. It is used to start the engine in cold conditions by supplying the air.

The methods that are used for starting large and medium size engines are,

1. Starting by an auxiliary engine
2. Use of electric motors or self starters
3. Compressed air system

1. Starting by an auxiliary engine

❖ In this system, an auxiliary engine is mounted closer to the main engine and drives the latter through a clutch and gears. The clutch is first disengaged and then the engine is started by a self starter motor.

2. Use of electric motors or self starters

❖ It is used in small diesel engine and gasoline engines the motor draws a heavy current and is designed to be engaged continuously for 30 seconds only after which it is required to cool off for a minute or so, and then reengaged.

3. Compressed air system

❖ It is used for starting large diesel engines. Compressed air at about 17 bar supplied from an air tank or bottle is admitted to few of the engines cylinders making them work like reciprocating air motors to run

the engine shaft.

The compressed air system includes the following

1. Storage tank/vessel
2. A safety valve
3. Interconnecting pipe work

4. <u>Fuel system</u>

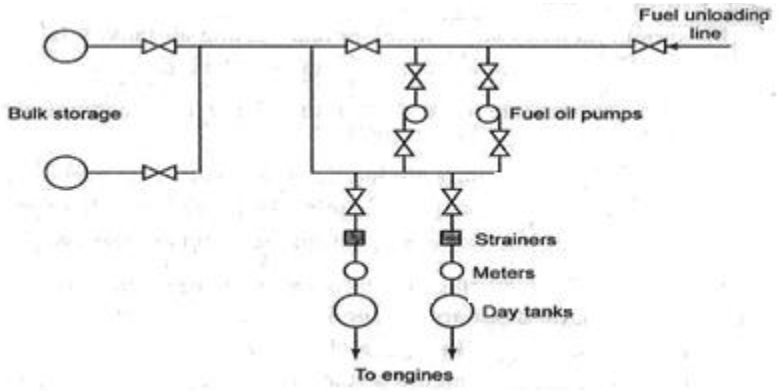


Fig-9- System of fuel storage for a diesel power plant

1. It includes the storage stamp, fuel transfer pump, strainers and heaters.
2. The fuel is supplied to the engine according to the load variation.

❖ The fuel oil may be supplied to the plant by trucks, tank cars and then through transfer pumps. It is transferred to small service storage tanks know as **engine day tanks.**

❖ The minimum storage capacity of at least a month's requirement of oil should be kept in bulk.

❖ Day tanks supply the daily fuel need of engines and may contain a minimum of above 8 hrs of oil requirement of the engines.

The fuel supply system is generally classified into .

1. Simple suction system
2. Transfer system

❖ In simple suction system, the oil is taken by a suction pump driven by engines from service tanks located few centimeters below the engine level. This system is used in small capacity plants.

❖ In a transfer system, the motor driven pump takes the oil from main storage to the day storage tank.

❖ The oil from day storage tank flows under gravity to the engine pump. This type of system is preferred for medium size or big size power plants.

The following things should be taken care of while operating the fuel supply system.

1. In all suction lines, the pipe joins should be made tight.
2. It has provisions for clean lines and for changing over the lines during emergencies
3. The piping between filter and the engine should be thoroughly oil flushed.

All oil lines should be put under air pressure and the joints tested with soap solution.

a. Fuel injection system

- The functions of the fuel injection system are to meter small amount of oil, inject into the cylinder at proper times, atomize and mix with the air. Mixing becomes more difficult with an increase in speed and increase in cylinder diameter.

Functions of a fuel injection system:

1. Filters the fuel.
2. It measures the correct quantity of fuel to be injected
3. Time the fuel injection
4. Atomize the fuel to fine particles.
5. It controls the rate of fuel injection.

Type of Fuel injection system

1. Common rail injection system.
2. Individual pump injection system
3. Distributor.

5. Lubrication system

- It includes oil pumps, oil tanks,, filter, cooler and pipes. It is used to reduce the friction of moving parts, and reduce wear and tear of the engine.

The various lubrication system used in IC engines may be classified as

1. Wet sump lubrication system.
2. Dry sump lubrication system.
3. Mist lubrication system.

1. Wet sump lubrication system

The various type of sump lubrication system are

1. Splash system
2. Semi-pressure system
3. Full pressure system

2. Dry sump lubrication system

- The lubricating oil stored in the oil sump is called wet sump system. But the system in which the

lubricating oil is not kept in the oil sump is know as dry sump system. 3. Mist lubrication system

❖ It is used in the two stroke cycle engines. Most of the two stroke engines are crank charged 1.e. they employ crank case compression. So, crank case lubrication is not suitable for two stroke engines. These engines are lubricated by adding 2 to 3% lubricating oil in the fuel tank.

6. Cooling system

❖ The temperature of burning fuel inside the combustion chamber is 1500^{o}C to 2000^{o}C. To maintain the temperature as a reasonable level, water is circulated around the engine in water jackets which is passed through the cylinder, piston, combustion chamber. Hot water leaving the jacket is sent to heat exchanger.

7. Governing system

❖ It is used to regulate the speed of the engine. This is done by varying the fuel supply according to the engine load.

8. Exhaust system

❖ The purpose of the exhaust system is to discharge the engine exhaust to the atmosphere outside the building. It includes silencers and connecting ducts.

❖ The exhaust gas has high temperature and so it is used to preheat the oil and air. The exhaust pipe should be short in length with minimum number of bends and should have one or two flexible tubing sections which take up the effects of expansion, and isolate, the system from the engine vibration.

4. Explain with a neat sketch the semi-closed cycle gas turbine power plant.(Nov/Dec 2011)

❖ Semi-closed cycle gas turbine plant combines the advantages of both open cycle plant, such as quick and case of start and closed cycle plant, such as constant efficiency at all loads and higher unit rating which permits the use of higher back pressure.

❖ In this semi-closed cycle gas turbine plant, part of the compressed gas is preheated by exhaust gases of combustion chamber and then expanded in a gas turbine drives the compressor, thus operating in a closed cycle.

❖ The remaining air is used in the combustion chamber to burn fuel. The combustion products after heating the air expand in a gas turbine to drive the generator before exhausting to the atmosphere. The line diagram of this process is shown in Figure 3.1

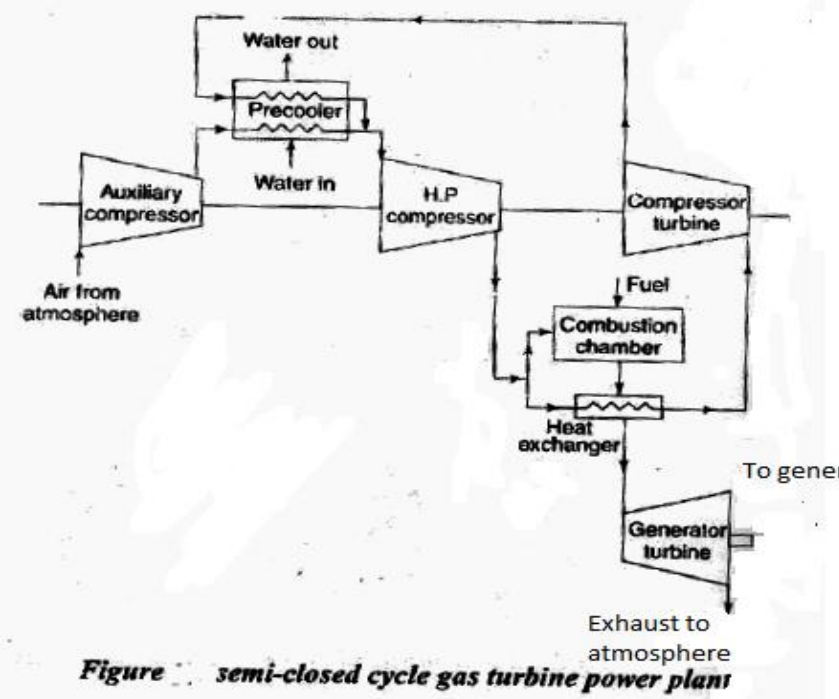


Figure semi-closed cycle gas turbine power plant

5. Draw a layout of diesel power plant, showing various systems and explain each system in detail (April/May 2012) (Nov/Dec 2012) or With the help of a diagram ,explainthe function of essential components of diesel power plants.(May/june 16)

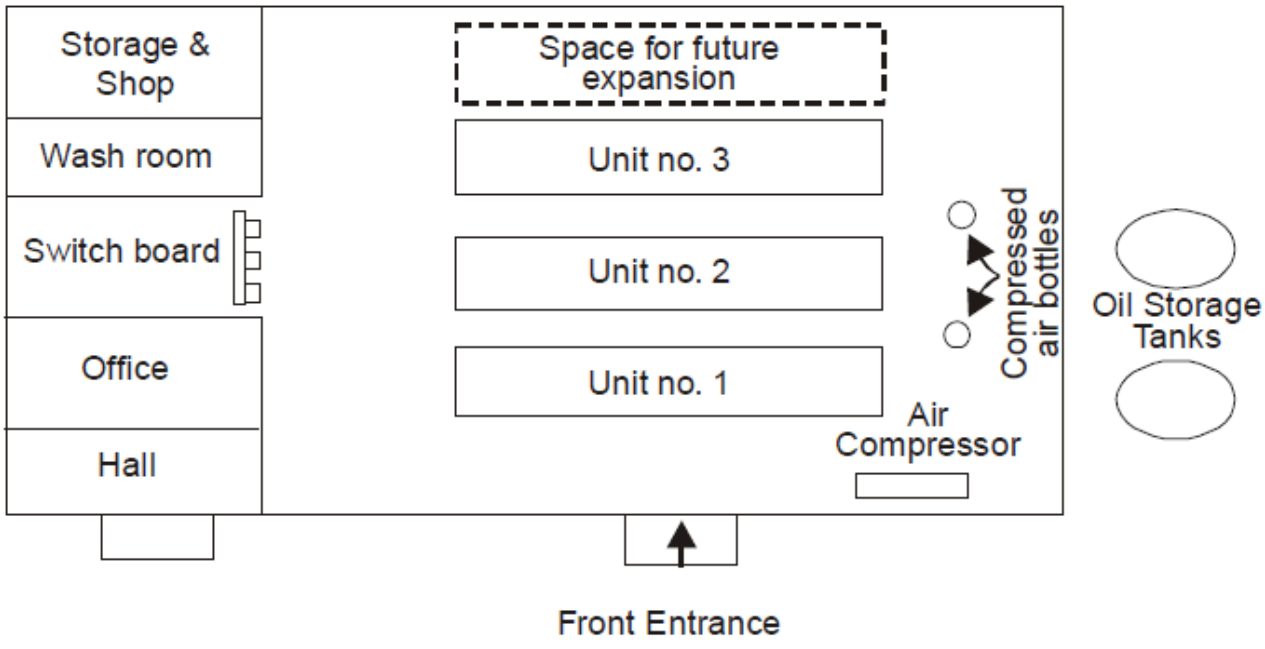


Fig 5.1 the layout of diesel power plant.

❖ Fig 4.1 shows the layout of diesel power plant. The most common arrangement for diesel engines is with parallel center lines, with some room left for extension in future the repairs and maintenance works

required large space.

❖ so, consideration should be given to that. The air intakes and filters are should be separated from the main engine room. Adequate space is provided for oil storage and repair. Shop should be provided close to the main engine room

6. Give the advantages and disadvantages of diesel engine power plants? (APR/MAY 2017)

Advantages:

1. Diesel power plants are cheaper.
2. It occupies less space
3. Plant layout is simple
4. Design and installation are very simple
5. Location of the plant is near to the load center
6. It is quick starting and easy pick up of loads
7. It requires less quantity of water and for cooling purposes
8. Skilled man power is not required
9. The diesel plants are more efficient than steam power plants in the range of 150MW capacity.
10. Requires less operating and supervising staff.
11. It will respond varying loads without any difficulty
12. Time schedule for manufacturing are shorter.
13. Diesel plant operates at high overall efficiency than steam plants.
14. Fuel handling is easier and no problem of ash disposal
15. Efficiency does not fall so much as that of a steam plant during parts loads
16. It has no stand by losses

Disadvantages:

1. The repair and maintenance costs are high
2. Plant capacity is limited to about 50MW of power
3. Life of the diesel plants is low when compared to thermal plants.
4. High operating cost
5. In a diesel power plant noise is a serious problem.
6. Diesel unit capacity is limited. It cannot be constructed in larger size.
7. The diesel power plant are not economized where fuel has to be imported.
8. The efficiency of the diesel engine is about 33% only.

7.Draw diagrams and explain the difference between open cycle and closed cycle gas turbines (April/May 2012) ,(May/june 16)or Explain the working of open cycle and closed cycle gas turbine power plant and discuss its advantage and disadvantage.(Nov/dec 15)(APR/MAY2017

❖ The most basic gas turbine unit in one operating on the open cycle in which a rotary compressor and a turbine are mounted on a common shaft as shown in fig 9.2.

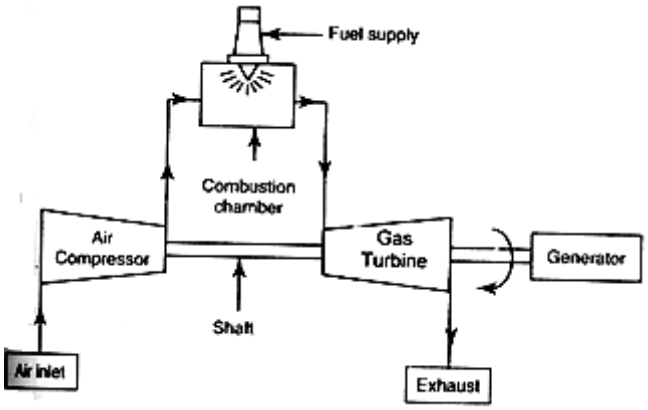


Fig 9.2. open cycle gas turbine power plant

❖ Air is drawn from the atmosphere into the compressor and compressed to pressure of 300 to 400 kN per m^2. The compressed air is then entered into the combustion chamber where the energy is supplied by spraying the fuel into a and ignited by hot gases.

❖ The hot gases expand through the turbine to produce the mechanical power. Then the burned gases are exhausted to the atmosphere. Then fresh air is drawn into the compressor for the next cycle.

❖ The process is repeated again and again. Here, the compressor is driven by turbine itself.

❖ In order to achieve the network output from the unit, the turbine must develop more gross work output then the work required to drive the compressor and to overcome mechanical losses in the drive.

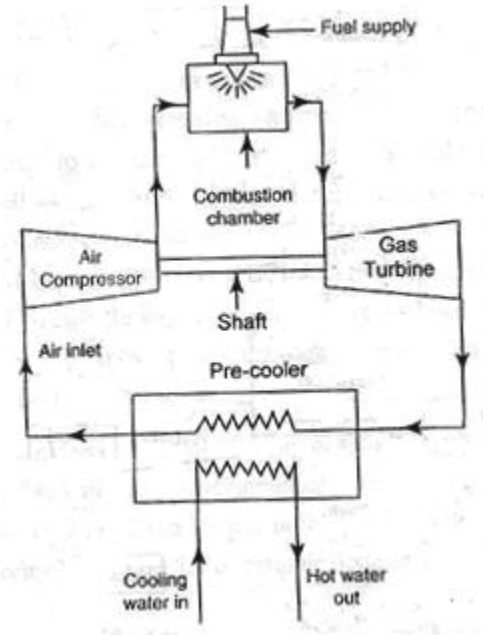
Opencycle:

Fig 7.2-closed cycle gas turbines

SI No.	Open cycle gas turbine	Closed cycle gasturbine
	Advantages	**Disadvantages**
1.	No pre-cooler is required because of burned gas from gas turbine exhausted to atmosphere	Separate pre-cooler arrangement is necessary.
2.	For the same powerdeveloped, the size and weight ofthe open cycle gas turbine unitare less.	The size and weight are more.
3.	Initial cost and maintenance costof the plant are less,	Initial cost andmaintenance cost are more.
4.	Combustionefficiency is more	Combustion efficiency is less
5.	Coolant isnot required, therefore, it is used for movingvehicle such as air craft, jet propulsion etc.	Coolant is required forpre cooler, therefore, it isused for stationary applications such aspower generation etc.
6.	The response to load variation is greater than closed cycle gas turbine	Coolant is required forpre cooler, therefore, it isused for stationary applications such aspower generation etc.

SI. No.	Open cycle gas turbine	Closed cycle gas turbine
	Disadvantages	**Advantages**
1	Part load efficiency decreases rapidly as the considerable Percentage of power developed by the turbine is used to drive the compressor.	Efficiency is same throughout the cycle.
2	Turbine blades are fouled by the combustion products.	Turbine blades do not wear away,since the

		combustion is external.
3	Starting of the plant is difficult.	Starting of the plant is easy.
4	As direct heating is used in open cycle plant, high quality fuels are required.	Low quality fuels can be used since the combustion is external.
5	Thermal stresses are high.	Thermal stresses are low.
6	Frequent internal cleaning of the system is necessary.	No need for internal cleaning.



8. Make a comparison of gas turbine power plant with diesel engine power plant of same capacity (Nov/Dec 2012)

S.No.	Gas turbine power plant	Diesel power plant
1	It is an ' external combustion. engine in which fuel is burnt outside theengine to obtain heat energy from fuel.	It Is an internal combustion engine in which fuel is burnt inside the engine cylinder to obtain heat energy from fuel.
2	The expansion of flue gas takes place in the turbine,	The Expansion takes place within the engine cylinder itself.
3	The power produced by this type of power plant could be stored and used l a t e r w h e n t h e requirements arise,	The power produced by diesel power plant is not stored but it is Operated Whenever the power requirements
4	The running of power plant will be continuous,	The running of power plant is intermittent.
5	This powerplant generally produces large amount of power and it is used as a peak load power plant.	Comparatively less amount of power is produced by this type of power plant.
6	Both installation cost and operating cost are higher.	Both installation cost and Operating cost are comparatively
7	It can be used in combined power plants.	The hybridization of diesel power plant with renewable energy power plant is possible and easy.
8	The use of individual gas turbine power plant by Both commercial and domestic sectors is not possible due to the reason that the gas turbine power plant cannot be Used as the emergency power	The use of individual diesel turbine power plant by both commercial and Domestic sectors is possible due To the reason that the gas diesel power plant can be used as the emergency power plant.

	plant.	
9	Maintenance duration and cost ofthepower plant will be more.	It is easy to maintain.
10	The power plant set up is not available even for the less power requirements.	The power plant set up is readily available which leads to reduce commissioning time.

10. Explain different components of gas turbine plant with neat sketch Elements of a gas turbine plant

The gas turbine plant consist of

1.Compressor

2.Intercooler

3.Regenerator

4.Combustion chamber

5.Gas turbine

6.Reheating units

1. **Compressor**

❖ In gas turbine plants, the axial and centrifugal flow compressors are used. In most of the gas turbine power plants, 2 compressors are used. One is low-pressure compressor and the other is high pressure compressors.

❖ In the low-pressure compressor, the atmospheric air is drawn into the compressor through the filter. The major part of the power developed by the turbine (about 66%) is used to run the compressor.

❖ This low pressure air goes to the high pressure compressor through the intercooler. Then the high pressure air goes into the regenerator.

2. Intercooler

❖ The intercooler is used to reduce the work of the compressor and it is place between the high pressure and low pressure compressor.

❖ Intercooler are generally used when the pressure ratio is very high. The energy required to compress the air is proportional to the air temperature at inlet. The cooling of compressed air in intercooler is generally done by water.

3. Regenerator

❖ Regenerators are used to pre-heat the air which is entering into the combustion chamber to reduce the fuel consumption and to increase the efficiency. This is done by the heat of the hot exhaust gases coming out of the turbine

4. Combustion chambers

❖ Hot air from regenerators flows to the combustion chamber and the fuel like coal, natural gas or kerosene or injected into the combustion chamber.

❖ After the fuel injection, the combustion take place. These high pressure, high temperature product of combustion are passed through the turbine.

5. Reheating units

❖ In this units, the additional fuel is added to the exhautsed gases coming out from the high pressure turbined, and the reheated combustion products goes into the low pressure turbine.

6. Gas turbine

Two types of gas turbine are used in gas turbined plant.

1.High pressure turbine

2.Low pressure turbine

❖ The combustion product from the combustion chamber is first expanded in high pressure turbine and then it expands in the low pressure turbine. Due to the expansionin the gas turbine, the heat is converted into mechanical work.

11. What is an engine day tank? State the functions of a fuel injection system (May/June 2013) (APR/MAY 2018)

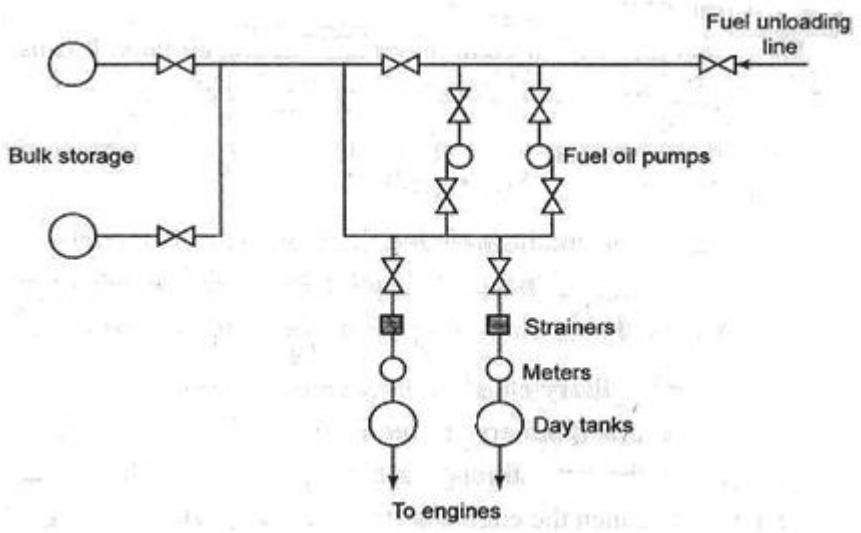


Fig 11.1 System of fuel storage for a diesel power plant

❖ It includes the storage stamp, fuel transfer pump, strainers and heaters. The fuel is supplied to the engine according to the load variation.

❖ The fuel oil may be supplied to the plant by trucks, tank cars and then through transfer pumps. It is transferred to small service storage tanks known as **engine day tanks.**

❖ The minimum storage capacity of at least a month's requirement of oil should be kept in bulk.

❖ Day tanks supply the daily fuel need of engines and may contain a minimumof above 8 hrs of oil requirement of the engines.

❖ The fuel supply system is generally classified into

1.Simple suction system

2.Transfer system

❖ In simple suction system, the oil is taken by a suction pump driven by engines from service tanks located few centimeters below the engine level. This system is used in small capacity plants.

❖ In a transfer system, the motor driven pump takes the oil from main storage to the day storage tank.

❖ The oil from day storage tank flows under gravity to the engine pump. This type of system is preferred for medium size or big size power plants.

❖ The following things should be taken care of while operating the fuel supply system.

1.In all suction lines, the pipe joins should be made tight.

2.It has provisions for clean lines and for changing over the lines during emergencies

3.The piping between filter and the engine should be thoroughly oil flushed.

❖ All oil lines should be put under air pressure and the joints tested with soap solution.

a. Fuel injection system

❖ The functions of the fuel injection system are to meter small amount of oil, inject into the cylinder at proper times, atomize and mix with the air.

❖ Mixing becomes more difficult with an increase in speed and increase in cylinder diameter.

Functions of a fuel injection system:

1.Filters the fuel.

2.It measures the correct quantity of fuel to be injected

3.Time the fuel injection

4.Atomize the fuel to fine particles.

5.It controls the rate of fuel injection.

Type of Fuel injection system

1.Common rail injection system.

2.Individual pump injection system

3.Distributor.

12.Explain water cooling system in diesel power plants with neat sketch.(May/June 2013).

Liquid cooling system is further classified as

(1) Open cooling system

(2) Natural circulation(Thermo-system)

(3) Forced circulation system

(4) Evaporation cooling system.

OPEN COOLING SYSTEM:-

- This system is applicable only where plenty of water available.
- The water from the storage tank is directly supplied through an inlet valve to the engine cooling water jacket.
- The hot water coming out of the engine is not cooled for reuse but it is discharged.

NATURAL CIRCULATION SYSTEM:-

- The system is closed one and designed so that the water may circulate naturally because of the difference in density of water at different temperatures. Fig 13.1 shows a natural circulation cooling system.

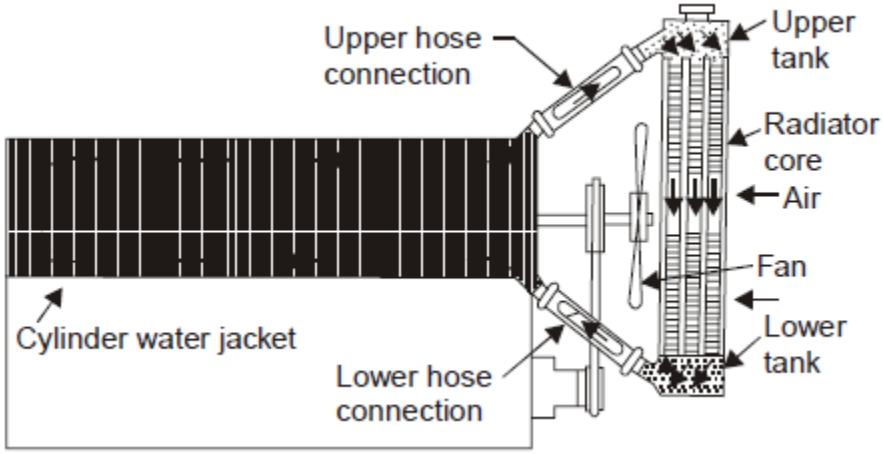


Fig 12.1 shows a natural circulation cooling system.

- It consists of water jacket, radiator and a fan. When the water is heated, its density decreases and its tends to rise, while the colder molecules tend to sink.
- Circulation of water then is obtained as the water heated in the water jacket tends to rise and the water cooled in the radiator with help of air passing over the radiator either by ram effect or by fan or jointly tends to sink.
- Arrows shows the direction of natural circulation, which is slow.

FORCED CIRCULATION COOLING SYSTEM:-

- Fig. 12.2 shows forced circulation cooling system that is closed one. The system consists of

pump, water jacket in the cylinder, radiator, fan and thermostat.

❖ The coolant (water or synthetic coolant) is circulated through a cylinder jacket with a help of a pump, which is usually a centrifugal type, and driven by the engine.

❖ The function of thermostat, which is fitted in the upper hose connection initially, prevents the circulation of the water below a certain temperature (usually up to 85 degree centigrade) through the radiation so that water gets heated up quickly.

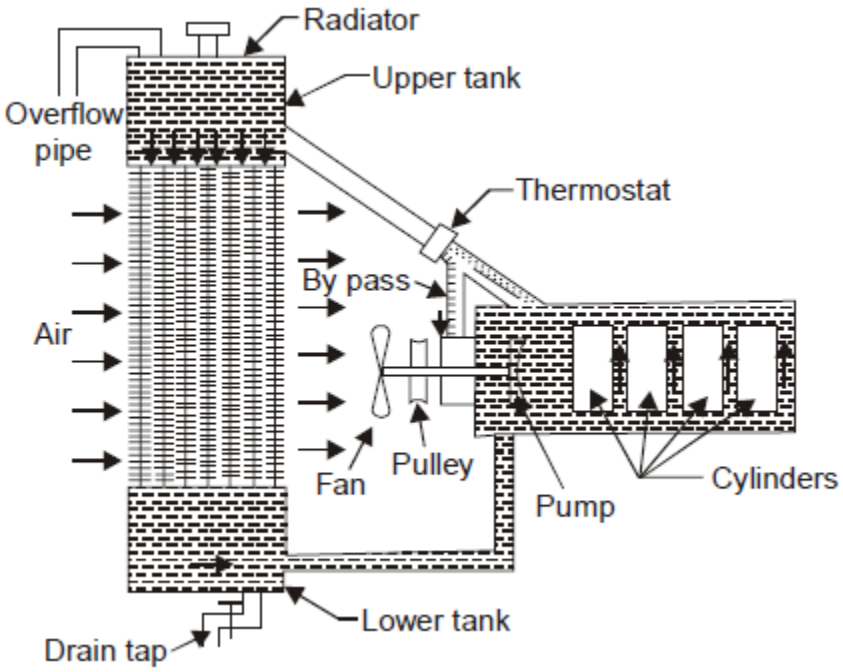


Fig. 12.2 shows forced circulation cooling system

❖ Standby diesel power plants up to 200 kVA use this type of cooling.

❖ In the case of bigger plant, the hot water is cooled in a cooling tower and re circulated again. There is a need of small quantity of cooling make-up water.

13. Consider a stationary power plant operating on an ideal brayton cycle. The pressure ratio of the cycle is 8 and the gas temperature at the compressor inlet and turbine inlet are 27°c and 1027 °c respectively determine the following.

1. Gas temperature at the compressor and turbine exit
2. Back work ratio and
3. Thermal efficiency

Assume Pr_1=1.386 and Pr_3=330.9

Pr- Relative pressure. [APR-05]

Given data:

Rp=8

T_1=27°c=300k,T_3=1027°c=1027+273=1300k

Pr_1=1.386,Pr_3=330.9

Solution:

Compression process [1-2]

$$T_2=(R_p)^{\frac{\gamma-1}{\gamma}} * T_1 = (8)^{1.4-1/1.4} * 300 = 543.43k$$

3-4 –compresion process

$T_3/T_4=(R_p)^{\frac{\gamma-1}{\gamma}}$ =1300/T_4=$(8)^{1.4 - 1/1.4}$

T_4=717.66k

Back work ratio =W_t-W_c/W_t=$m_{cp}(T_3-T_4)-m_{cp}(T_2-T_1)/m_{cp}(T_2-T_1)$

=$(T_3-T_4)-(T_2-T_1)/ T_3-T_4$

=(1300-717.66)-(543.43-300)/1300-717.66=0.582

Thermal efficiency η=1-1/ $(R_p)^{\gamma-1/\gamma}$=1-1/$(8)^{1.4-1/1.4}$=44.8 %

14. A diesel power station is to supply power diamond of 30kw .If the overall effiency of the power generating unit is 40% calculated the following

Amount of diesel oil required per hours
The electric energy generated per hour of the fuel oil.
The clarification value of fuel oil used is 12000kcal/kg

Solution:

Efficiency =output/input

Output=30kw

Efficiency =40%=0.4=output/input

Input=30/0.4=Input=75kw

Input per hour =75 ×1 =75kwh

1kwh=860kcal

Fuel oil required =64500/12000

Fuel oil required=5.37kg

Input per tonne of fuel oil

$=1\times1000\times12000\text{kcal}$

$=12\times10^6\text{kcal}$

$=12\times10^6/860$

$=13954\text{kwh}$

Efficiency =output/input

Output=0.4×13954

Output=5581k

15. Write a short note on combined cycle power plant.[MAY/JUNE 2013] or Discuss why combined cycle power generation is so important in present day energy scenario.(May/june 16)(Nov/Dec 2016)(APR/MAY 2018)

❖ The maximum steam temperature in a power cycle exceeds 600◦ C but the pulverised coal furnace temperature is about 1300◦C. so there is a lot of energy wasted in the power plant.

❖ To increase the efficiency and reduce the fuel, the combined power cycles are introduced by superposing high temperature power plants as a topping unit to the low temperature as a bottoming unit.

The combined plants may be of the following types:

- Gas turbine – steam turbine power plant
- MHD- gas turbine power plant
- Gas turbine and combined cycle cogeneration plant

Gas turbine – steam turbine plant

❖ It is the combination of simple gas turbine power plant and steam power plant.

❖ The two cycles of gas turbine steam turbine power plant are connected in series , the topping cycle on Baryton cycle and the bottoming one operating on Rankine cycle.

❖ In the gas turbine unit the heat from the exhausted gas turbine is recovered by a heat recovery boiler and the steam is produced by using this heat in the boiler and it goes to the steam turbine . here two generator are produce the power.

❖ One generator is connected to the gas turbine unit and the other generator is connected to the steam turbine unit .so the overall heat rejection will be reduced. As a result of this of this the overall efficiency will increase .it is given by

the 1,2 are the thermal efficiencies of the brayton cycle and the steam cycle respectively. The achievable overall efficiency may be in the range of 40% - 45%.

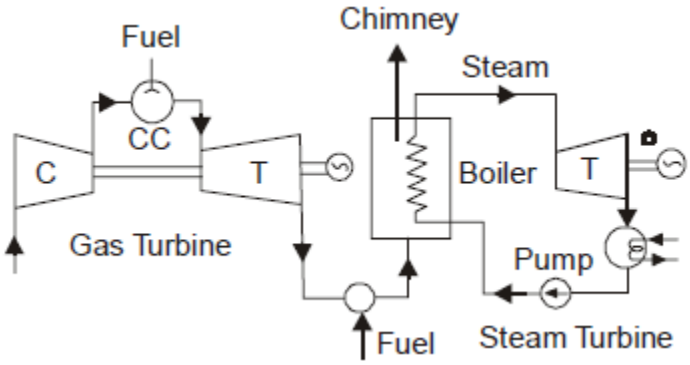
MHD- gas turbine power plant:

❖ One MHD and one gas turbine power plant are connected in series which means heat rejected by MHD plant is fully utilised to heat the air inside the combustion chamber in gas turbine power plant

.by this heat rejection by the cycle is reduced drastically so that the efficiency of the combined cycle will increase.the overall efficiency can be obtained as 70%- 72%.

Gas turbine and combined cycle cogeneration plant:

❖ The power plant which produces both thermal and electrical energy is called a cogeneration plant.



Combined cycle (Co- generation)

❖ By this, the conversion efficiency of 33% for electricity and 53% for thermal output are captured. The remaining 14% goes as waste heat. In usual cycles, the air after expansion in the turbine is condensed in condenser.

❖ The steam is produced by using heat rejected by using heat rejected by air in the condenser.

❖ The device in which steam is produced is known as heat recovery generator(HRSG) . the steam is further works.

❖ The cogeneration cycles are mainly used in process heating, absorption cooling and space heating operation.

17.Write a short notes on integration combined cycle (IGCC) or Explain in detail about the construction and working of IGCC.(Nov/dec 15) or What is IGCC system?Brief.(May/june 16),(May/june 17)

Integration combined cycle

❖ Gasification of coal is the cleanest way of utilization of coal, while combined cycle power generation gives the highest efficiency.

❖ Integration of these two technologies in IGCC power generation offers the benefits of very low emissions and efficiencies of the order of 44-48%.

❖ Integrated Gasification Combined Cycle (IGCC) is rapidly becomingone of the most promising technologies in power generation.

❖ IGCC systems are extremely clean and much more efficient than traditional coal-fired systems.

❖ They use a combined cycle format with a gas turbine driven by the combusted syngas from the gasifier, while the exhaust gases are heat exchanged with water/steam to generate superheated steam to drive a steam turbine.

❖ IGCC is a combined cycle process fuelled by coal whichisgasified by heating it in a gasifier in the presence of steam and oxygen.

❖ The resulting fuel gas is made up mainly of hydrogen and carbon monoxide, and when it is cleaned of impurities and burnt in a gas turbine, it produces electricity, carbon dioxide and water vapour.

❖ The waste heat from the gasification process is also partially recovered and used to generate steam which drives a steam turbine, providing a second 'cycle' to generate electricity.

Construction of IGCC:

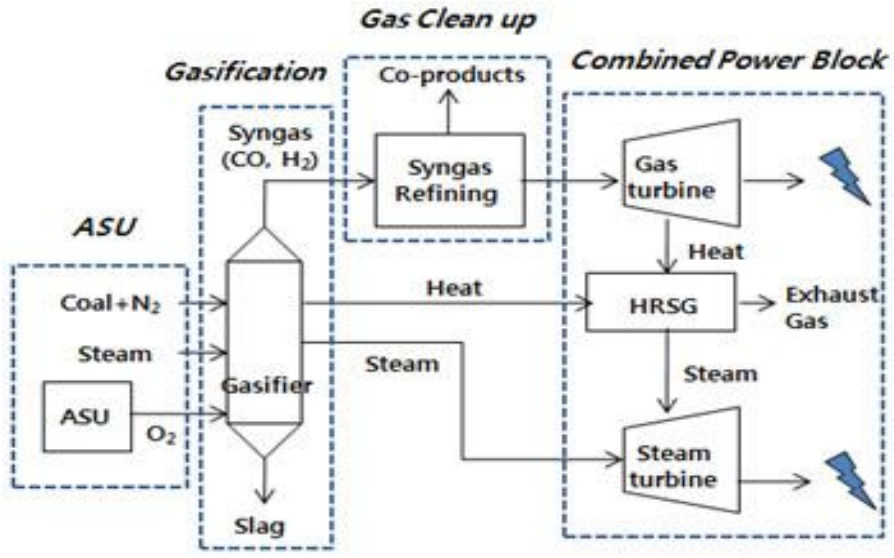
The layout IGCC is shown in the fig 2.IGCC plant consist of four major units

(1) **ASU(Air Separation Unit):** This unit supplies oxygen and steam required for gasification

(2) **Gasfication:** This unit consist of coal gasifier where Conversion of solid fuel into combustible syngas occurs

(3) **Gas clean up**: Filtering out the impurities in syngas will take place at this unit

(4) **Combined power block**: It consist of Steam turbine and Gas turbine for power production



17.1 The layout IGCC

Working:

❖ Coal is gasified, either partially or wholly, and the synthetic gas produced after cleanupis burnt in the combustion chamber of the gas turbine.

❖ The main features of the cycle are shown in Fig. 17.1. Coal and limestone are fed to a pressure vessel, the coal being gasified by oxygen and steam.

❖ The ash and limestone form a molten slag which is discharged and the synthetic gas produced is cooled.

❖ The use of air instead of oxygen produces a gas of lower calorific value. The exhaust gases from the GT raise steam in the HRSG.

❖ Several different forms ofgasifier have been developed, e.g. Texaco, Shell, Dow, Lurgi and so on.

❖ The thermodynamic performance o f an IGCC power plant studied by Nag and De (1998) shows that there is an optimum pressure ratio for the gas cycle at a given temperature ratio (T3/T0) for maximum overall cycle efficiency.

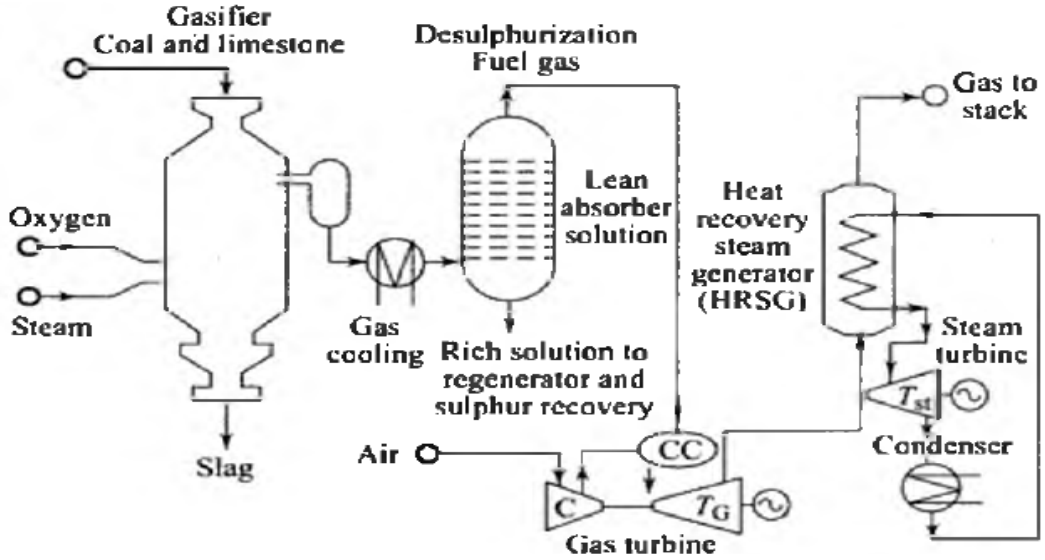


Fig:17.2Integrated Gasifier combined plant

Advantages:

- ❖ Advantages of IGCC over current conventional coal-based power generation systems include: Higher efficiencies and lower emissions:
- ❖ Improvements in efficiency dramatically reduce emissions from coal combustion as the graph at right highlights. Increasing efficiency from 35 to 40%, for example, reduces carbon dioxide emissions by over 10%.\
- ❖ With efficiencies currently approaching 50%, IGCC power plants use less coal and produce much lower emissions of carbon dioxide than conventional power plants.
- ❖ With development of new gas turbine concepts and increased process temperatures efficiencies of more than 60% are being targeted.
- ❖ Product flexibility – including carbon capture and hydrogen production: The gasification process in IGCC enables the production of not only electricity, but a range of chemicals, by-products for industrial use, and transport fuels

18. Write a brief note on starting system of gas turbine? (APR/MAY 2018)

STARTING SYSTEMS:

Two separate systems-starting and ignition are required to ensure a gas turbine engine will start satisfactorily. During engine starting the two systems must operate simultaneously.

Types of Starter

The following are the various types of gas turbine starter.

(*i*) A.C. and (*ii*) D.C.

- A.C. cranking motors are usually 3 phase induction types rated to operate on the available voltage and frequency.
- D.C. starter motor takes the source of electrical energy from a bank of batteries of sufficient capacity to handle the starting load. Engaging or disengaging clutch is used.

(b) Pneumatic or Air Starter:

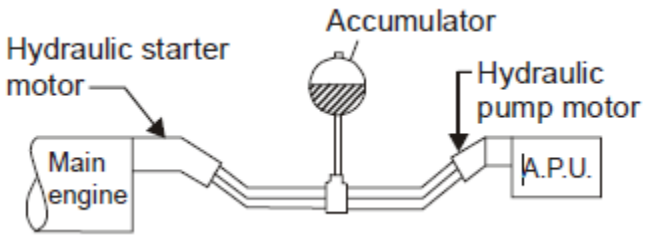
- Air starting is used mostly as it is light, simple and economical to operate. As air starter motor has a turbine rotor that transmits power through a reduction gear and clutch to the starter output shaft that is connected to the engine.
- The starter turbine is rotated by air pressure taken from an external ground supply, from an auxiliary power unit carried in the aircraft or from an engine that is running. An electrical control unit controls the air supply to the starter by opening the pressure-reducing valve.
- When an engine starter is selected and is automatically closed at a predetermined starter speed the clutch also automatically disengages as the engine accelerates. It is most suitable for natural gas pipeline gas turbine drive.

(*c*) Combustion Starter:

- It is in every respect a small gas turbine. It is a completely integrated system which incorporates a planetary reduction gear drive with over-running clutch. The unit is started with the electric starter. The starter turbine is directly geared to the gas turbine shaft through a reduction gear.

(d) Hydraulic Starting Motor:

- It consists of a hydraulic starter motor for main engine, an accumulator, a hydraulic pump motor for auxiliary power unit (A.P.U.).



Hydraulic Starter Motor

- Discharging the hydraulic accumulator to power a hydraulic pump motor starts APU. The hydraulic pump motor is driven with APU (Fig. 9.16) to start main engine and recharge accumulator. It is suitable for aircraft engine better.

UNIVERSITY PROBLEMS

1.A gas turbine plant of 800kW capacities takes the air at 1.01 bar and $15 \circ C$.The pressure ratio of the cycle is 6 and maximum temperature is limited to $700 \circ C$. A regenerator of 75% effectiveness is added in the plant to increase the overall efficiency of the plant. The pressure drop in the combustion chamber is 0.15 bars as well as in the regenerator is also 0.15 bars. Assuming the isentropic efficiency of the compressor 80% and of the turbine 85%. Determine the plant thermal efficiency. Neglect the mass of the fuel. (Nov/Dec 2013)(NOV/DEC 2017)

$$P_4 = 1.01+0.15=1.16\text{bar}$$

Solution:

The arrangement of the components is shown in figure and the processes are represented on T-s diagram as shown in figure.

The given data is

$$T_1 = 15 + 273 = 288\text{K}$$

$$P_1 = 1.01\text{bar}$$

$$P_2 = 1.01\text{x}6 = 6.06\text{bar}$$

$$R_p = \frac{P_2}{P_1} = 6$$

Pressure at point 4 =6.04-0.15=5.91 bar

Applying isentropic law to the process 1 – 2

Applying isentropic law to the process $4\_5'$

$T_2{}' = T_1 (R_P)^{(\gamma-1/\gamma)} = 288(6)^{0.286} = 480\text{k}$

$$\eta_C = \frac{(T_2{}' - T_1)}{(T_2 - T_1)}$$

But $T_2 = T_1 + \eta_C (T_2{}' - T_1) = 288 + 0.8(480 - 288) = 528\text{k}$

$$P_3 = 6.06 - 0.15 = 5.91\text{bar}$$

$$\eta = \frac{\text{Indicated Thermal Efficiency}}{\text{Air Standard Efficiency}} = \frac{0.4478}{0.62} = 72.23\%$$

The effectiveness of the regenerator is given by,

$$T_5{}' = \frac{T_4}{\left[\left(\frac{P_3}{P_4}\right)^{\left(\frac{\gamma-1}{\gamma}\right)}\right]} = \frac{(700+273)}{\left[\left(\frac{5.91}{1.16}\right)^{0.286}\right]} = 612\text{K}$$

$$\eta_t = \frac{(T_4 - T_5)}{(T_4 - T_5)}$$

or $T_5 = T_4 - \eta_t (T_4 - T_5{}') = 973 - 0.85(973 - 612) = 666\text{K}$

$$\varepsilon = \frac{(T_4 - T_5)}{(T_4 - T_5)}$$

$$T_3 = T_2 + 0.75(T_5 - T_2) = 528 + 0.75(666 - 528) = 631.5KW$$

$$W_C = C_P(T_2 - T_1) = 1X(528 - 288) = 240KJ/Kg$$

$$W_t = C_P(T_4 - T_5) = 1X(973 - 666) = 307KJ/Kg$$

$$W_n = W_t - W_C = 307 - 240 = 67kJ/Kg$$

$$Q_S = C_P(T_4 - T_5) = 1X(973 - 631.5) = 341.5KJ/Kg$$

$$\eta_{th} = \frac{W_n}{Q_s} = \frac{67}{341.5} = 0.196 = 19.6\%$$

2. A four – stroke diesel engine has a piston diameter of 16.5cm and a stroke of 27 cm. The compression ratio is 14.3, the cut – off 4.23% of the stroke and the mean effective pressure 4.12 bar. The engine speed is 264 rev/min and the fuel consumption is 1.076 kg of oil per hour, having aalorific value of 39150 kJ/kg. Calculate the relative efficiency of the engine. (Nov/Dec 2013)
Solution:

I.P = $\frac{P_m LAn}{(60X1000X2)}$, for two stroke engine (APR/MAY 2018)

Given :

$P_m = 4.12bar$

L=0.27m

A = $\frac{\Pi}{4}$ x $(0.165)^2$=0.214m^2

N = 264

I.P = $\frac{(4.12 x 10^5 x 0.27 x 0.0214 x 264)}{(60 x 1000 x 2)}$ = 5.24kw

Now, indicated thermal efficiency= $\frac{(\text{Heat equivalent of I.P per hour})}{(\text{Heat in fuel per hour})} = \frac{(5.24 x 3600)}{(1.07 x 39150)}$ = 44.78%

Now air standard efficiency = 1- $\left(\frac{r^{1-k}}{k}\right)\left(\frac{(\rho^k - 1)}{\rho - 1}\right)$

If clearance volume is taken as unity,then

R=14.3,

$\rho = 1+[(4.23x13.3)100]=1.56$

K=1.4

Efficiency =1-$\left[\frac{(14.3)^{-0.4}}{1.4}\right]\left[\frac{(1.56^{1.4}-1)}{(1.56-1)}\right]$=62%

3) Consider a stationary power plant operating on an ideal brayton cycle. The pressure ratio of the cycle is 8 and the gas temperature at the compressor inlet and turbine inlet are 27°c and 1027 °c respectively determine the following.

1. Gas temperature at the compressor and turbine exit
2. Back work ratio and
3. Thermal efficiency

Assume Pr_1=1.386 and

Pr_3=330.9 Pr- Relative pressure.

Given data:

Rp=8

T_1=27°c=30k

T_3=1027°c=1027+273

=1300k

Pr_1=1.386

Pr_3=330.9

Solution:

Compression process [1-2]

$T_2=(R_p)^{\frac{\gamma-1}{\gamma}} * T_1 = (8)^{1 4\_ 1/1 4 *}$

300 =543.43k

3-4 –compresion process

$T_3/T_4=(R_p)^{\gamma- 1}$

$1300/T_4=(8)^{1.4 - 1/1.4}$

T_4=717.66k

Back work ratio =W_t-W_c/W_t=$m_{cp}(T_3-T_4)-m_{cp}(T_2-T_1)/m_{cp}(T_2-T_1)$ =$(T_3-T_4)-(T_2-T_1)/ T_3-T_4$

=(1300-717.66)-(543.43-300)/1300-717.66

=0.582

Thermal efficiency η=1-1/ $(R_p)^{\gamma-1/\gamma}$

=1-1/(8)1.4-1/1.4

=44.8 %

4) A diesel power station is to supply power diamond of 30kw .If the overall effiency of the power generating unit is 40% calculated the following

Amount of diesel oil required per hours

The electric energy generated per hour of the fuel oil. The

clarification value of fuel oil used is 12000kcal/kg **Solution:**

Efficiency =output/input

Output=30kw

Efficiency =40%

0.4=output/input

Input=30/0.4

Input=75kw

Input per hour =75 ×1 =75kwh

1kwh=860kcal

Fuel oil required =64500/12000 Fuel oil

required=5.37kg

Input per tonne of fuel oil

=1×1000×12000kcal =12×10^6kcal

=12×10^6/860 =13954kwh

Efficiency =output/input

Output=0.4×13954 Output=5581k

5.A 2-cylinder C.I. engine with a compression ratio 13:1 and cylinder dimensions of 200mm × 250mm works on two stroke cycle and consumes 14kg/h of fuel while running at 300 r.p.m. The relative and mechanical efficiencies of engine are 65% and 76% respectively. The fuel injection is effected upto 5% of stroke. If the calorific value of the fuel used is given as 41800 kJ/kg, calculate the mean effective pressure developed? (APR/MAY 2018)

Solution

Also, $V_3 - V_2 = 0.05V_s = 0.05(V_1 - V_2)$

or, $V_3 - V_2 = 0.05(13V_2 - V_2), \ \frac{V_1}{V_2} = 13$

or, $V_3 - V_2 = 0.06V_2$

$$\frac{V_3}{V_2} = 1.6$$

$$\eta_{\text{air standard}} = 1 - \left\{\frac{1}{\gamma(r)^{\gamma-1}}\right\}\left[\frac{(\rho^{\gamma-1})}{(\rho-1)}\right]$$

$$= 1 - \left\{\frac{1}{1.4(14)^{1.4-1}}\right\}\left[\frac{(1.6^{1.4}-1)}{(1.6-1)}\right] = 0.615 = 61.5\%$$

$$\eta_{\text{relative}} = \frac{\eta_{\text{thermal}}}{\eta_{\text{air standard}}}$$

$$0.65 = \frac{\eta_{\text{thermal}}}{0.615}$$

Diameter of cylinder, $D = 200 \text{ mm} = 0.2 \text{ m}$

Stroke length, $L = 250 = 0.25 \text{ m}$

Number of cylinders, $n = 2$

Compression ratio, $r = 14$

Fuel consumption $= 14 \text{ kg/h}$

Engine speed, $N = 300 \text{ r.p.m.}$

Relative efficiency, $\eta_{\text{relative}} = 65\%$

Mechanical efficiency, $\eta_{\text{mech}} = 76\%$

Cut-off $= 5\%$n of stroke

Calorific value of fuel, $C = 41800 \text{ kJ/kg}$

$k = 1$ for two-stroke cycle engine V_3

Cut-off ratio, $p = \frac{v_3}{v_2}$

$$\eta_{thermal} = 0.4$$

But, $$\eta_{thermal} = \frac{I.P.}{(mf \times C)}$$

$$0.4 = \frac{I.P.}{\left[\left(\frac{14}{3600}\right)41800\right]}$$

$$I.P. = 65 \text{ KW}$$

$$\eta_{mech} = \frac{B.P.}{I.P.}$$

$$0.76 = \frac{B.P.}{65}$$

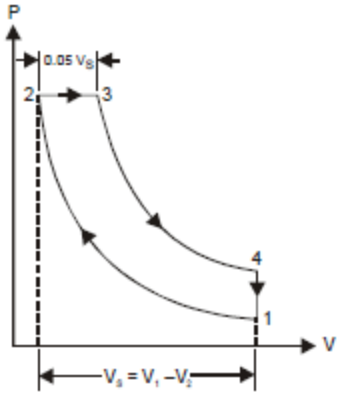


Fig. 8.18

$$B.P. = 49.4 \text{ kW}$$

Mean effective pressure can be calculated based on I.P. or B.P. of the engine

$$I.P. = \frac{(n.p_{mi}.\ LANk.10)}{6}, \quad p_{mi} = \text{indicated mean effective pressure}$$

$$65 = \frac{2 \times p_{mi} \times 0.25 \times \frac{\pi}{4}(0.2)^2 \times 300 \times 1 \times 10}{6}$$

$$p_{mi} = 8.27 \text{ bar}$$

and brake mean effective pressure (p_{mb}) = 0.76 × 8.27 = 6.28 bar.

QUESTION BANK

PART A

1. What are the main units in gas turbine power plants? (Anna Univ. Dec 2005)
2. How the gas turbine blades are cooled? (Anna Univ. Dec 2008)
3. Mention the various processes of the Brayton cycle (Anna Univ. Oct 1996),(Nov-Dec 2016)
4. Draw the p-V and T-s diagram of Brayton cycle.(Anna Univ. April 2005) (or)Sketch the limited pressure cycle on p-V and T-s diagram and name various processes.(Anna Univ.Oct 2002)
5. Sketch the schematic arrangement of open cycle gas turbine plant and name the components.(Anna Univ. April 2004)
6..Discuss the effect of inter cooling in a gas turbine plant. (Anna Univ. June 2007)
7.What is the principal of operation of simple jet propulsion system? (Anna Univ. Nov 2003)
8.Why is the maximum cycle temperature of gas turbine plant much lower than that of diesel power plants? (Anna Univ. June 2009)

9.List out the inherent advantages of the combined power cycles. (Anna Univ. June 2007)
10. What are all the application of the diesel power plant? (Anna Univ. June 2007, Dec 2008 and April/May 2010)
11. State the merits and demerits of closed cycle gas turbine over open cycle gas turbine power plant.(April/May 2010)
12. State the fuels used in the gas turbine power plant(April/May 2011)
13. What is mean by combined cycle power plant? (April/May2011)
14. List the a fuel differences between the closed cycle and open cycle gas turbine power plant.(Nov/Dec 2011)
15. What are the functions of lubrication system? (Nov/Dec 2011)
16. What are the methods by which the efficiency of an open cycle gas plant can be improved? (April/May 2012)
17. What is meant by regeneration? (April/May 2012)
18.What are the methods by which thermal efficiency of a gas turbined power plant be improved? (Nov/Dec 2012)
19 What is the basic difference between a diesel engine and a steam turbined? (Nov/Dec 2012)
20.What you meant by regeneration in gas turbine power plant (May/June 2013)
21. How the soild injection system is classified? (May/June 2013)
22. .Write the classification of gas turbine? (Nov/Dec 2013)
23. Write two advantages of diesel poweplants?(Nov/Dec 2013)
24.What you meant by regeneration in gas turbine power plant (May/June 2013), (Nov/Dec 2016)
24.
25.Write the classification of gas turbine? (Nov/Dec 2013), (Nov/Dec 2016)
26.What is meant by regeneration? (April/May 2012)(Nov/Dec 2016)
27.What are all the application of the diesel power plant? (Anna Univ. June 2007, Dec 2008 and April/May 2010),(April/May 2017).

PART B

1. Explain various power cycles.)Pg.No :10
2. Discuss briefly the methods employed for improvement of thermal efficiency of open gas turbine power plant (April/May 2010)Pg.No :16(or)
Write detailed technical notes on the following i)Regeneration (April/May 2011) (May/June 2013)
ii)Reheating
3.List the essential components of a diesel power plants and explain them briefly? (April/May 2010)Or With a neat sketch explain in detail, about the component and layout of diesel engine power plant (April/May 2011)Or List the various components of diesel engine power plant and explain its functions with neat sketch (Nov/Dec 2011),(Nov-Dec 2016)Pg.No:22
4. Explain with a neat sketch the semi-closed cycle gas turbine power plant.(Nov/Dec 2011)Pg.No:28
5. Draw a layout of diesel power plant, showing various systems and explain each system in detail (April/May 2012) (Nov/Dec 2012) Pg.No.29
3.Draw diagrams and explain the difference between open cycle and closed cycle gas turbines (April/May 2012) Pg.No:29
7. Make a comparison of gas turbine power plant with diesel engine power plant of same capacity (Nov/Dec 2012)Pg.No:30
8. Write note on open cycle gas turbine power plant (May-june 2017). (Nov/Dec 2012) Pg.No:33
9. What is an engine day tank? State the functions of a fuel injection system (May/June 2013)Pg.No:34
10. Explain water cooling system in diesel power plants with neat sketch.(May/June 2013).Pg.No:35

PART-A

1. What factors control the selection of particular type of reactor?

1. Type of fuel to be used.
2. Output power in MW.
3. Control systems and coolant system.
4. Safety of reactor.
5. Rate of neutron production and absorption.

2. What is the chain reaction?

❖ When a high energy unstable neutron struck with heavy nucleus of uranium the nucleus splits in to fragments and release 2 to 3 neutrons per fission accompanied with release of enormous amount of heat.

❖ The neutrons released during fission can strike other nuclei and can cause further fission till the whole fissionable material is disintegrated. This self-sustaining reaction is known as chain reaction.

3. What is fast breeder-reactor? List down any two types? (Apr/May 2018)

❖ The fast breeder reactor is one that uses enriched uranium or plutonium or thorium that is produce in the reactor itself as secondary fuel. The different types of fast breeder reactors are

1. Liquid metal cooled reactor
2. Fermi fast breeder reactor

4.What is the function of moderator and reflector used in nuclear power plant?(may/june16)

Moderator:-

It is a material which reduces the kinetic energy of fast neutron to increase the probability of chain reaction.

Reflector:-

It is used to reflect the escaping neutrons back into the core

5.Name of the coolants used for fast breeder reactor

1. Liquid metal (Na or NaK)
2. Helium (He)
3. Carbon di oxide (CO_2).

6. Define the term "Breeding"

❖ It is the process of producing fissionable material(secondary fuel) from the fertile material such as uranium 238 (U^{238}) and thorium 232 (Th^{232}) by absorbing the neutron with conversion ratio above unity.

7. What are the components used in pressurised water reactor nuclear power plant.

1.Reactor core

2. Control Rods.
3. Moderator and Coolant.

4.Pressuriser.

5. Steam generator.
6. Turbine

7. Condenser.

8. Pump.

8. What are the important properties that a control rod should posses? (NOV/DEC 2017)

1. It should have adequate heat transfer properties
2. It should withstand high temperature
3. It should be able to shutdown the reactor in normal and emergency conditions.
4. Non corrosive.

9. What are the important properties that a moderator should posses?

1. It should have high thermal conductivity
2. It should withstand high temperature
3. It should be able to slow down the neutrons when required
4. Non corrosive.
5. It should have high melting point for solid moderator and low melting point for liquid moderator.

10.How the nuclear reactor is classified according to the type of moderator used?

1. Graphite reactor.
2. Beryllium reactor.
3. Water (ordinary or heavy water) reactor.

11. Define multiplication factor?

- It is used to determinewhether the chain reaction will continue at steady state or not.

Effective multiplication factor K=P

Where P-rate of production of neutrons.

A-Combined rate of production of neutrons.

E- Rate of leakage of neutrons.

12. Indicate the types of nuclear fission reactor power plants operating in india.(Anna Univ. May/June 2006)

1.Pressurised Heavy Water Reactor-Narora-1&2,UP.

2.Pressurised Heavy Water Reactor-Gujarat, Kakrapar.

3.Pressurised Heavy Water Reactor-Kalpakkam, Tamilnadu.

4. Boiling water reactor-Tarapur Maharashtra
5. CANDU-Ranapratapsagar.

13. Give the few details about the atomic power station currently operating in Tamilnadu. (May/June 2006)

1. Kalpakkam Atomic power station

-Fully indigenous material and designed by Indian engineers

-Capacity 700 MW

-PHWR

2. Kundangulam Atomic power station

-Collaboration with Russia.

-Capacity 2000 MW

-PHWR

14. What are the advantages and disadvantages of nuclear power plant? (Nov/Dec 2005)

Advantages:-

1. Power generation is more economic when compared with thermal plant.
2. Fuel transportation, handling and storage charges are absent.
3. No ash disposal problems.

4. Power production is not affected by weather conditions.
5. Space requirement is less.
6. Capital loss is low for bigger unit sizes.
7. Less number of workers are needed than thermal plant.
8. Water quantity required is very less.
9. Enormous amount of heat can be generated from small quantity of fuel consumption.
10. It is well suited for large power requirements.
11. Highly reliable operation.
12. Nuclear power plant has no effect on atmosphere by pollution.

Disadvantages:-

1.Disaster is the major safety problem faced by nuclear power plants due to nuclear explosions.
2.Radioactive wastes may affect the health of workers and other surrounding people.
3.High initial cost and maintenance cost.
4.Nuclear waste disposal is a major problem.
5. Nuclear plants require well trained personals for its operation..

15.Define-Nuclear fission? (April/May 2011),(May/June 2012),(Nov/Dec14)

❖ Nuclear fission is the process of splitting up of heavy unstable nucleus into two equal fragments of the equal mass and two to three neutrons accompanied by the release of large amount of heat.

16.Define- Nuclear fusion?.(April/May 2012)

❖ Nuclear fusion is forming heavier nuclei by colliding two or more nuclei so that they fuse together into heavier nuclei accompanied with the large amount of energy release.

17.Differentiate nuclear fission and fusion.

S.No	Nuclear fission	Nuclear fusion
1	Nuclear fission is the process of splitting up of heavy unstable nucleus into two equal fragments of the equal mass and two to three neutrons accompanied by the release of large amount of heat.	Nuclear fusion is forming a heavier nuclei by colliding two or more nuclei so that they fuse together into a heavier nuclei accompanied with the large amount of energy release.
2	Nearly about one thousands of the mass can get converted into energy.	Nearly about four thousands of the mass can get converted into energy.
3	Fission process emits radioactive rays	Lesser or no more radioactive rays emission in fusion process.
4	Process is possible even at ordinary operating temperature.	Very high temperature is needed for fusion process to occur.
5	It is possibly gives rise to self-sustained chain reactions in controlled manner.	It does not give rise to chain reaction in controlled manner.
6	Neutrons are emitted as a result of fission reaction.	Protons emitted as a result of fusion reaction.

18. What are the advantages and disadvantages of PWR?

Advantages:-

1.Single fluid used is water which is cheaper, available in plenty and multipurpose (coolant, moderator and reflector).

2.Reactor is more compact and higher power density.

3.Lesser number of control rods is required.

4. Steam is free from contamination by radiation and hence normal turbine maintenance is enough.

5.Fuel is utilized efficiently and thus minimizes the fuel cost.

Disadvantages:-

1.High primary loop pressure requires strong and leak proof pressure vessel and so high capital cost.

2.Low pressure in the secondary circuit leads to poor thermodynamic efficiency of the plant.

3.Use of high pressure, high temperature water causes severe corrosion problems.

4.Reactor must be shutdown foe fuel recharging.

5.Fuel reprocessing is difficult as fuel suffers radiation damage.

6. Preparation of fuel element is expensive.

19. Define Demand for electricity.(Nov/Dec 2013)

❖ Electricity demand is the amount of electricity being consumed at any given time. It rises and falls throughout the day in response to a number of things, including the time and environmental factors.

20.What are isotopes?(Nov/Dec 2013)

❖ Some elements exist in different forms. Mass number of these different forms is different, but the atomic number is the same. They are known as isotopes of the element

21.What is an LMFBR? Why is a liquid metal the preferred coolant in a fast breeder reactor? (May/June 2013)

❖ A liquid metal fast breeder reactor (LMFBR) is a nuclear reactor capable of producing more fissile product than it takes in. Breeders exhibit remarkable fuel economy compared to light water reactors.

❖ Liquid metal use in fast breeder reactors has long been considered for the improvement of efficiency in their heat transfer systems. Work has been performed around the world on corrosion of sodium-and potassium-cooled fast breeder reactor.

❖ In the LMFBR, the fission reaction produces heat to run the turbine while at the same time breeding plutonium fuel for the reactor.

22.Whatdo you mean by mass defect? (May/June 2013)

❖ During interaction two or more particles interact to combine together, the total mass of the system will decrease to be less than the sum of the masses of the individual particles.The stronger the interaction becomes, the more the mass will decrease. This decrease of the mass of the system is called the mass defect.

23.Name the different types of fuels used in nuclear reactors.(Nov/Dec 2012)

Uranium, Plutonium and Thorium.

24.What is a purpose of a moderator in a nuclear reactor? (Nov/Dec 2012) or What do you understand by moderation? Why it is essential? (May/june 15)

❖ Moderator is a device used to slow down the high energy fast moving neutrons by reducing their kinetic energy so that neutrons are utilized completely before it escapes.

❖ This increases the possibility of absorption of the neutron by the fuel to cause further fission and hence the quantity of fuel required to maintain a chain reaction is also reduced.The common moderators used are ordinary water, heavy water, graphite and beryllium.

25.What is meant by Radioactivity or radioactive decay?(Nov/dec14)

❖ It refers to the german name of Radio-Aktivität. Radioactivity is the spontaneous disintegration of atomic nuclei. The nucleus emits particles, β particles, or electromagnetic rays during this process.

26. What is the unit of Radioactivity?

1.Roentgen
2. RAD (Radiation Absorbed Dose)
3. RBE (Relative Biological Effectiveness)
4. REM (Roentgen Equivalent in Man)
5.Gray (GY)-100 rads
6. Sievert (SV)

27. What are the types of Radioactive decay?

1. Alpha decay
2. Beta decay
3. Gamma decay
4. Poistronemission (Beta positive decay)
5. Electron capture

28. Define-Decay timing.

❖ The number of decay events – d N expected to occur in a small interval of time dt is proportional to the number of atoms present. If N is the number of atoms, then the probability of decay (-d N/N) is proportional to dt.

29. What is Uranium enrichment?

❖ In most types of reactor, a higher concentration of uranium is used to make fuel rod.This produced by a process termed enrichment. The enriched uranium containing more than natural 0.7% U-235.

30. What are the two ways of uranium enrichment?

1.Gas centrifuge process
2. Gas diffusion

31. What is the purpose of reprocessing of nuclear waste?

❖ The used fuel contains 96% uranium,1% plutonium and 3% radioactive wastes.Reprocessing is used to separate the waste from the uranium and plutonium which can be recycled into new fuel.

❖ The reprocessing effectively reduces the volume of waste and limits the need to mine new supplies of uranium, so that extending the time of resources.

32. What is Neutron life time?

❖ The prompt neutron lifetime, is the average time between the emission of neutrons and either their absorption in the system or their escape from the system. The term lifetime is used

because the emission of a neutron is often considered its birth, and the subsequent absorption is considered its death.

33. What is Uranium-235 chain Reactor?

❖ In a chain reaction, particles released by the splitting of the atom go off and strike other uranium atoms splitting those. Those particles given off split still other atoms in a chain reaction. If an least one neutron from U-235 fission strikes another nucleus and causes it to fission, Then the chain reaction will continue.

34. What is four factor formulas?

❖ The four factor formula is used in nuclear engineering to determine themultiplication of a nuclear chain reaction in an infinite medium. The formula is:

- Reproduction Factor - The thermal utilization factor
- The resonance escapes probability - The fast fission factorEEE,

35. List the four types of radiation associated with nuclear fission.

1. Alpha radiation
2. Beta radiation
3. Gamma radiation
4. Neutron radiation

36. Define Alpha radiation.

❖ This is basically the atomic nucleus of the element (He) consisting of two protons and two neutrons. It is not very penetrative and the danger to man arises if an alpha emitting element, such as plutonium, then the alpha radiation be very damaging.

37. Define Beta radiation.

❖ Beta radiation consists of electrons or their positively charged counterparts. This can penetrate the skin, but not very far.

38. Define Gamma radiation.

❖ Gamma radiation is penetrative in a manner similar to X-rays and has similar physical properties. It can be stopped only by thick shields of lead or concrete.

39. Define Neutron radiation.

❖ Neutron radiation consists of the neutrons emitted during the fission process.Neutrons are also very penetrative, but less so then gamma-radiation.

40. Define water as moderator.

❖ Neutrons from fission have very high speeds and must slow greatly by water moderation to maintain the chain reaction. The Uranium-235 is enriched to 2.5-3.5% to allow ordinary water to be the moderator. Enough spontaneous events occur to initiate a chain reaction if the proper moderation and fuel density is provided.

41. List the types of Nuclear reactors.

The reactors are classified based on the following:

1. Type of fuel used
2. Neutron flux spectrum
3. The coolant

42. List the various widespread power plant reactor types.

1. Pressurized water reactor (PWR)
2. Boling water reactor(BWR)

3. Pressurized Heavy water reactor (PHWR)
4. Liquid metal fast Breeder Reactors (LMFBR)
5. High temperature Gas cooled reactors (HTGCR)

43. What is a pressurized water reactor (PWR)?

❖ The PWR belongs to the light water type. The moderator and the coolant are both light water (H2O). The cooling water circulates in two loops, which are fully separated from one another. PWR keep water under pressure, so the water heats but does not boil even at the high operating temperature.

44. What is boiling water reactor (BWR)?

❖ In a boiling water reactor, Light water plays the role of moderator and coolant as well. Part of the water boils away in the reactor pressure vessel, thus a mixture of water and steam leaves the reactor core.

45. What is Molten Salt Reactor (MSR)?

❖ A molten salt reactor is a type of nuclear reactor where the primary coolant is a molten salt. Molten salt refers to a salt that is in the liquid phase that is normally a solid at standard temperature ionic liquid, although technically molten salts are a class ofionic liquids.

46. Nuclear Power plant -safety.

Radiation doses can be controlled through the following procedures:

1. The handling of equipment via remote in the core of the reactor
2. Physical shielding
3. Limit on the time a worker spends in areas with significant radiation levels
4. Monitoring of individual doses and of the working environment
5. Safety mechanism of a Nuclear power reactor

47. List the Nuclear power plants in India.

1. Kaiga(3*22MWPHWR), Karnataka
2. Kakrapar(2*22MWPHWR), Gujarat
3. Kudankulam(2*100MWPWR), Tamilnadu
4. Madras(2*17MWPHWR), Tamilnadu

48. Define mean generation time.

❖ It is the average time from a neutron emission to a capture results in fission. The mean generation time is different from prompt neutron lifetime because the mean generation time only includes neutron absorption that leads to fission reaction.

49. What are the requirements of fission process?(April/May 2010)

- ❖ The neutrons emitted in fission must have adequate energy to cause fission of other nuclei.
- ❖ The number of neutrons produced must be able not only to sustain the fission process but also to increase the rate of fission.
- ❖ The fission process must liberate the energy.
- ❖ It must be possible to control the rate of energy liberation.

50. What are the essential components of a nuclear reactor?(April/May 2010)
(APR/MAY 2018)

(i)Reactor core
(ii) Moderator
(iii) Control rods

(iv) Reflector
(v)Cooling system
(vi)Reactor Vessel
(vii)Biological shielding

51. Distinguish between PHWR and LMFBR.April/May 2011)

s.No.	PHWR	LMFBR
1.	In a primary circuit, all components of reactor, pumps, heat exchangers are not separate In the secondary circuit, water is used as a working fluid.	In a primary loop, all components of reactor, pumps, heat exchangers are separate and independent In the secondary loop, sodium is used as a working fluid.
2.		

52. What is known as binding energy? (Nov/Dec 2011)

❖ The energy released at the moment of combination of two nucleons to form nucleus of an atom is called"binding energy".

53. What is the function of pressurizer in pressurized water reactor?(Nov/Dec 2011)(May/June 17).

❖ The pressure in the primary circuit should be high so that the boiling of water takes place at high pressure. This enables water to carry more heat from the reactor.

❖ The pressurising tank keeps the water at about $14MN/m^2$ so that it will not boil. Electric heating coil in the pressuriser boils the water to form the steam which is collected in the dome as more steam is forced into the dome by boiling, its pressure rises and pressurises the entire circuit.

54. Name the three moderators commonly used in nuclear power reactor. (April/May 2012)

❖ Heavy water (D_2O), Water (H_2O), Beryllium (Be), Graphite(C) and Helium (He) gas are commonly used moderators.

55.Compare nuclear fission with nuclear fusion?(May/june 14)

Nuclear Fission	Nuclear Fusion
Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter atoms into a larger one
Fission reaction does not normally occur in nature.	Fusion occurs in stars, such as the sun
Fission produces many highly radioactive particles.	Few radioactive particles are produced by fusion reaction, but if a fission "trigger" is used, radioactive particles will result from that.

56.What are the desirable properties of good moderators?(May/june 14)

❖ There are several common moderators used in nuclear reactors,such as graphite, beryllium and heavy water. These materials are selected as moderators on the basis of some very specific properties and requirements.

Graphite Moderators-hermally stable, but at elevated temperatures it can react with oxygen

and carbon dioxide in the reactor decreasing the effectiveness

Ordinary Water & Heavy Water Moderators-

1.It can perform satisfactorily with natural uranium fuel also; it yields highly enhanced neutron economy

2.Unlike graphite moderator, it does not oxidize

57.Distinguish between fertile and fissile material?(May/june 15)

Fertile material	Fissile material
The fissile material is the one which undergoes nuclear fission (splitting of atom) upon bombardment by slow/fast neutrons	Fertile material is the one which by itself is not fissionable but will capture the neutron and will get converted to a fissile material.
The fissile materials used are Uranium 235, Plutonium239 and Uranium233.	Examples are Uranium 238 becoming Plutonium 239. Thorium 232 becoming Uranium 233 etc

58.How do you cater for safety of nuclear power plant?(Nov/dec 15)

❖ Nuclear Power Plants in India have sufficient safeguards by way of design features, operating practices and regulatory controls against any major radiological releases based on.

1. Proper design, plant layout and adequate shielding
2. Limits of air contamination levels in different zones of the plant:
3. Source control by proper selection of materials/components

59.List the function of control rods?(Nov/dec 15)

The function of control rod is:

- ❖ To control the rate of fission.
- ❖ To start the nuclear chain reaction when reactor is started from cold.
- ❖ To shut down the reactor under emergency condition.
- ❖ To maintain the chain reaction at a steady state.
- ❖ To prevent the melting of fuel rods

60.What are fast nuclear reactor?(May/june16)

A fast nuclear reactor is one type of nuclear reactorin which fission chain reaction is sustained by fast neutrons. Such reactor needs no neutron moderator,but must use fuel that is relatively rich in fissile material when compared to that required for thermal reactor.

61.What is a CANDU type reactor?(may/june 16)

The word CANDU stands for "Canada Deuterium Uranium".It is pressurized heavy –water moderaroe and cooledpowerreactor.The special features of CANDU reactor is D_2O (deuterium oxide 99.8%)is mostly used moderator and coolant as well as neutron reflector.In CANDU reactor,the fuel used natural uranium as fuel(0.7% U^{235}).

62. Why shielding is necessary in nuclear power plants? (Nov/Dec 16)

❖ Shielding is necessary to protect the walls of the reactor vessel from radiation damage and also protects the operating personnel from exposure to radiation.

❖ Thick layers of lead concrete or steel are provided all around the reactor. These layers absorb the gamma rays, neutrons etc.

63. What is critical mass of nuclear fuel?(Nov/Dec 16)

A critical mass is the smallest amount of fissile material needed for sustained nuclear chain reaction. The critical mass of a fissionable material depends upon its nuclear properties.

Uranium-235; critical mass = 52

Plutonium-238; critical mass = 9.04-10.07

64. Give typical examples for control rods? (NOV/DEC 2017)

- Boron
- Cadmium
- Hafnium

65. **Define electron volt with reference to nuclear power plant?(NOV/DEC 2017)**

- It is defined as the amount of energy an electron gains after being accelerated by 1 volt of electricity. The electron volt is used to measure energy.
- Symbol is eV

PART-B (16 Marks)

1. Briefly explain the pressurized water reactor (PWR) with neat sketch.(May/June 2013) (Nov/Dec 2011) or Draw the diagram of PWR and BWR and explain advantages and disadvantages .What are the condition which prefer PWR over BWR and viceversa?(May/June 15) or Explain the necessity of pressurizer in a PWR power plant.(may/june 16) (NOV/DEC 2017)(APR/MAY 2018)

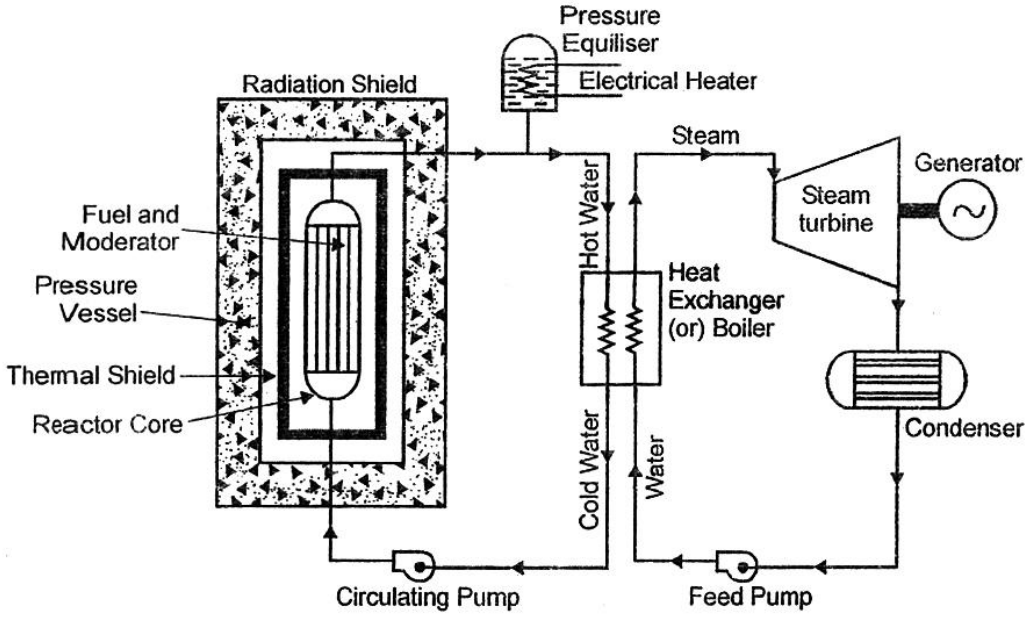


Figure 1.1 PWR Power plant

- Water is an excellent moderator and coolant for the reactor and thus water cooled reactor are developed in nuclear power plants. PWR power plant shown in fig 1.1uses enriched uranium as fuel.
- The water under pressure is used here for both moderator and coolant. A constant pressure of about 150 bar is maintained in the primary loop so as toavoid the boiling of water.
- In this reactor, a pressuriser is mounted in which water and steam is filled and provided with a electric heater at bottom and water spray at the top. If the pressure in primary loop drops.

- The heater is opened which generates steam and increases the steam content in the vessel so that pressure is increased in the primary loop.
- If the pressure in primary loop is high, then too high cold water is sprayed in to the steam and so the steam gets condensed so that pressure is reduced in the primary loop.
- Inside the reactor, continuous chain reaction takes place and is accompanied by the liberation of a large amount of heat which is absorbed by the coolant (water).
- This hot pressurised coolant flows to heat exchanger (steam generator) through pressuriser. Here, heat exchanger acts as steam generator.
- The steam is generated by transferring the heat from the coolant to the feed water of secondary loop. Then, the pump returns the coolant into the reactor again through primary loop.
- The steam generated in heat exchanger is expanded in the turbine which is coupled with the generator.
- From the turbine exit, the condensate passes to condenser and it condenses. The feed pump delivers the same as feed water to the heat exchanger.

Advantages:-

1.Single fluid used here is water which is cheaper, available in plenty and multipurpose (coolant, moderator and reflector).

2. Reactor is more compact and higher power density.

3. Lesser number of control rods is required.

4. Steam is free from contamination by radiation and hence normal turbine maintenance is enough.

5. Fuel is utilized efficiently and thus maximizes the fuel cost.

Disadvantages:-

1. High primary loop pressure requires strong and leak proof pressure and so high capital cost.
2. Low pressure in the secondary circuit leads to poor thermodynamic efficiency of the plant.
3. Use of high pressure, high temperature water causes severe corrosion problems.
4. Reactor must be shutdown for fuel recharging.
5. Fuel reprocessing is difficult as fuel suffers radiation damage.
6. Preparation of fuel element is expensive.

Condition which prefer PWR over BWR:

- The **boiling water reactor** (**BWR**) is a type of light waternuclear reactor used for the generation of electrical power.
- It is the second most common type of electricity-generating nuclear reactor after the pressurized water reactor (PWR), also a type of light water nuclear reactor.
- The main difference between a BWR and PWR is that in a BWR, the reactor core heats water, which turns to steam and then drives a steam turbine.
- In a PWR, the reactor core heats water, which does not boil. This hot water then exchanges heat with a lower pressure water system, which turns to steam and drives the turbine.

2. Explain boiling water reactor (BWR)with neat sketch. Give its advantage and disadvantage. (May/June 2013) (April/May 2011) (Nov/Dec 2010)or With the help of neat sketch ,explain the working of boiling water reactor and discuss its advantage and disadvantage?(May/June 14) or Draw the diagram of PWR and BWR and explain

advantages and disadvantages .What are the condition which prefer PWR over BWR and viceversa?(May/June 15). Or List and briefly the characyeristics features of a BWR.(may/june 16) (May/ June 17) (NOV/DEC 2017)

Boiling water reactor

❖ Boiling water reactor also uses enriched uranium as a primary fuel. Here, the reactor pressure is essentially reduced to allow the boiling of coolant (feed) water. Figure 3.5 illustrates the BWR power plant.

❖ This system is also known as direct cycle boiling water reactor power plant. In this reactor, the steam is generated inside the reactor itself.

❖ Coolant (water) enters the reactor at the bottom and gets heated by the heat liberated due to the fission reaction. Inside the reactor itself, the water is completely converted into steam.

❖ The steam is leaves the reactor top and supplied to the steam turbine and gets expanded.

❖ Exhaust steam from the turbine passes through the condenser and condensed. The condensed water is rerouted again by using feed pump.

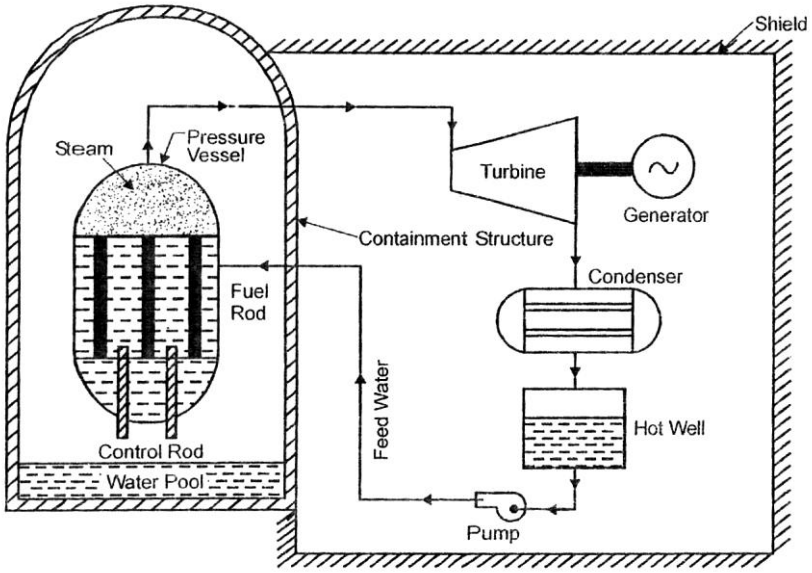


Figure 2.1: BWR Power plant

Advantages:-

1. Elimination of heat exchanger results in reduction cost.
2. Maintenance of comparatively lower pressure inside the reactor makes the reactor much lighter and reduces the cost.
3. Low metal surface temperature.
4. Thermal efficiency is high of about 30% due to single loop operation.

Disadvantages:-

1.Steam leaving the reactor is slightly radioactive.

2.Safety is a major problem in BWR plants than PWR plants .

3.Steam wastage during part load operation results in lower thermal efficiency.

4.Lower power density makes to use larger vessel.

3.Briefly explain the Fast Breeder Reactor (FBR) with a neat sketch.(Nov/Dec 2010)

Fast Breeder Reactor

❖ Fast breeder reactor is a small vessel in which the chain reaction is sustained primarily by fast moving neutrons (without using moderator). In fast breeder reactor, fuel such as enriched uranium and plutonium or a mixture of these is kept inside the reactor core without using moderator.

❖ This active core region is surrounded by a blanket of breeding material (fissible Material) such as fertile uranium to absorb the excess neutrons otherwise those neutrons would possibly lost by leakage.

❖ The reactor core is cooled commonly by liquid sodium. Fast breeder reactors are normally designed to produce more amount of fissible material than that is being consumed by it.

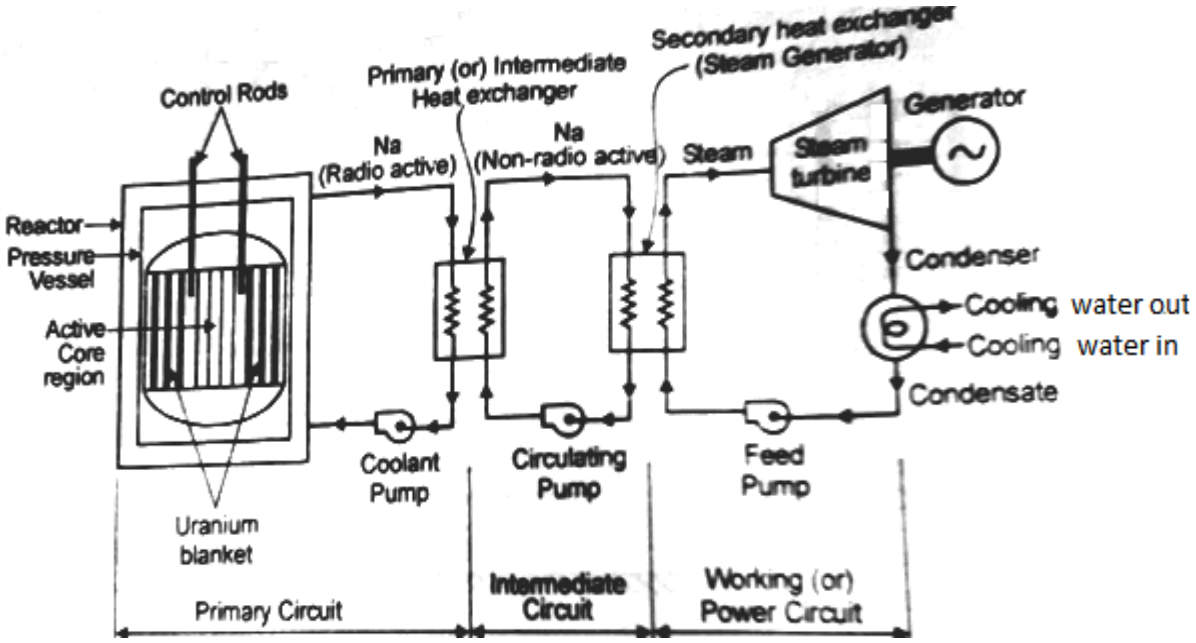


Fig.3.1 Fast breeder reactor power plant (liquid metal cooled reactor).

❖ The figure 3.1 shows the fast breeder reactor power plant which is more similar to liquid metal (sodium graphite) cooled reactor plant.

❖ When the enriched uranium undergoes fission reaction, heat will be liberated with the release of fast moving neutrons.

❖ Excess neutrons are absorbed by the surrounded uranium blanket and are converted into fissionable material (Pu^{239}) which is cabaple of sustaining chain reactions continuously.

❖ Heat evolved in the reaction is carried by the primary coolant(sodium) and given to the primary heat exchanger.

❖ In primary heat exchanger the heat is transferred to the secondary coolant (sodium , however different coolant could be used).

❖ The hot secondary coolant passes throughthe secondary heat exchanger (steam generator) and the feed water coming from the condenser is heated and converted into steam.

❖ It is then supplied to steam turbinefor mechanical power. The electric power is produced by coupling an electric generator to the steam turbine.

Advantages:-

1. It does not require moderator.
2. High breeding is possible.
3. High power density makes to use small core.

4. More fuel is produced than consumed.
5. Absorption of neutrons is low.

Disadvantages:-

1. It requires highly enriched fuel and thus initial cost is very high.
2. Safety is essential against melt-down.
3. Circulation of special coolants are essential to carry out large quantity of heat from the reactor core.
4. Handling of sodium is difficult as it becomes highly radioactive.

4.What are the advantages and disadvantages of nuclear power plants compared to other conventional power plants.(Anna Univ. April/ May 2012) (Nov/Dec 2010)

Advantages:-

1. Power generation is more economic when compared with thermal plant.
2. Fuel transportation, handling and storage charges are absent.
3. No ash disposal problems.
4. Power production is not affected by weather conditions.
5. Space requirement is less.
6. Capital loss is low for bigger unit sizes.
7. Less number of workers are needed than thermal plant.
8. Water quantity required is very less.
9. Enormous amount of heat can be generated from small quantity of fuel consumption.
10. It is well suited for large power requirements.
11. Highly reliable operation.
12. Nuclear power plant has no effect on atmosphere by pollution.

Disadvantages:-

1.Disaster is the major safety problem faced by nuclear power plants due to nuclear explosions.
2.Radioactive wastes may affect the health of workers and other surrounding people.
3.High initial cost and maintenance cost.
4.Nuclear waste disposal is a major problem.
5. Nuclear plants require well trained personals for its operation.

5.Explain different methods for nuclear waste disposal with necessary sketch.(May/June 2013)

The nuclear waste from the reactor is classified as

(i) High level waste
(ii) Medium level waste and
(iii) Low level waste.

<u>High level waste</u>

❖ The high level waste has radioactivity above 1000 curie. The medium level waste radioactivity lies 100 to 1000 curie and low level waste radioactivity is below 100 curie.

❖ The spent fuel is withdrawn from the reactor and placed in a water pond where heat is removed and shorter lived radio nuclides decay.

❖ The pond water is continually treated to remove activity due to release of fuel from defective cladding.

❖ The spend fuel is then transferred to the reprocessing plant where cladding that contains the fuel to removed and the fuel is dissolved in nitric acid. The U^{235} (20 to 90%) and PU^{239} are then removed leaving 99% non-volatile fission products behind in solution behind in solution know as "Highly Active Liquid Waste:.

❖ The separated U^{235} and Pu^{239} are further purified and either stored for future use or fabricated into fresh fuel for reactor.

❖ The waste from the cooling pond (known as central storage) is then transferred to intermediate storage and kept there for a period of 30 to 100 years where most of the reaction heat and radioactive nature is reduced to a considerably low level.

❖ Then the waste is permanently shifted in the final storage where it is permanently buried either in the earth or sea.

Disposal of Low Level Solid Waste

❖ The nuclear waste of this category is cast in cement in steel drum. These drums are buried either below the soil (a few metres) or kept at the bed of the ocean.

❖ The safety of the method lies in the vast dilutions of the activity as it disperses at the bottom of the ocean. Radio logically, the disposal of waste in this category to sea seems to be the best option to avoid risks due to unnecessary handling and storage.

Disposal of Medium Level Solid Waste

❖ These wastes are mainly contaminated with neutrons activation product isotopes.

❖ They are incorporated into cement cylinders as cement is non-combustible and provides shielding against external exposure. Another ability of cement is resistance to leaching by ground water.

Disposal of High Level Liquid Waste

❖ An underground system used in West-Germany for the storage of tanks is shown in Figure. A cavity is excavated at 511 m in salt mine and the cylinders are stored in this cavity as shown in figure.

❖ It has a special advantage as salt is strong absorber of radioactive emissions and has good thermal conductivity which helps to keep the temperature within acceptable limit.

❖ This arrangement is for intermediate storage where these cylinders are kept for 30 to 100 years and then they are discharged for final disposal still below the intermediate storage in the ground or discharged into the sea bed.

❖ The final storage is providing with 10 cm thick lead wall surrounded by 6 mm titanium. Both materials are corrosive resistant and also serve as a shield to prevent radio-emission to ground water.

❖ This facility can store 10,000 waste containers (each of 40 cm in diameter 1.5m of height) and require nearly 1 km2 are for the whole facility.

6.What is known as nuclear fission? What are the essential requirements to cause nuclear fission? (Nov/Dec 2011) (Nov/Dec 2012)(May/ June 17). Or Name the four reactions involving Deuterium in a fusion reactor. Which one is achieved quite early? (NOV/DEC 2017)

Nuclear fission

❖ Nuclear fission is the process of splitting of nucleus into two almost equal fragments accompanied by releasing the heat.

❖ In other words, it is the process of splitting of unstable heavy nucleus into two fragments of approximately equal mass when bombarded with neutrons.

❖ The fission fragments formed due to fission are the isotopes. The nuclear binding energy per fragment is more than that of heavy nuclei. Thus, there is a considerable release of energy during the process. This process is accompanied by the emission of neutrons and gamma rays.

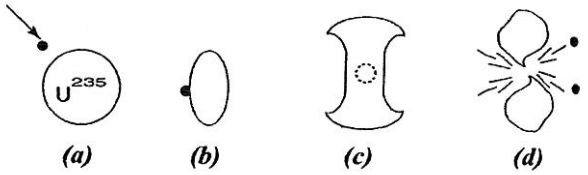


Figure 6.1 Nuclear fission

❖ The fission phenomenon is explained with the fig. 6.1 (a) refers the pre-fission stage.

❖ Neutron reaches the U^{235}nucleus. Fig. (b) refers the collision of neutron with nucleus and the nucleus is in the excited state. At this stage, it attains the shape of a dumb-bell.

❖ Fig. (d) Refers the post fission stage. The nucleus is split into two fragments. Two free neutrons are ejected with high with high velocity.

❖ The above process is possible only, if the nucleus is excited to the sufficient energy and attains the stage (c).

❖ The excitation energy required to split the nucleus is called "Critical energy". The critical energy should be more than the neutrons binding energy.

❖ During the fission process, a large amount of enegy is released and the fission fragments are associated with high velocities. These fragments collide with other nuclei in the mass are stopped.

❖ The associated velocity energy is converted into heat which is large amount of energy obtained from the fission.

❖ One neutron obtained from fission interacts with another U^{235} nucleus and thus, it undergoes fission process. Thus, the process is self-sustaining.

❖ To sustain the fission process, the following requirements must be fulfilled.

(i)The neutrons emitted in fission must have adequate energy to cause fission of other nuclei.

(ii) The number of neutrons produced must be able not only to sustain the fission process but also to increase the rate of fission.

(iii)The fission process must liberate the energy.

(iv)It must be possible to control the rate of energy liberation.

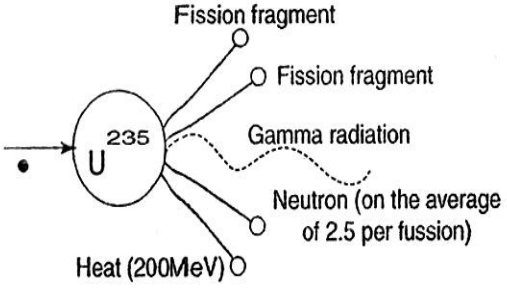


Fig. fission of Uranium 235

❖ Fig represents the fission of Uranium 235. When a neutron is captured by a nucleus of an atom of U-235, U-236 isotope forms.

❖ This is highly unstable type of isotopic. Uranium perhaps one millionth of a second. It splits roughly into two equal parts and liberates a total energy of 200 MeV.

❖ The products formed include the fission fragments, neutrons and gamma rays.

❖ The fission products absorb most of total energy released by the fission as kinetic energy which is converted in to heat as the fragment collide when a neutron causes fission of U^{235}, a typical reaction produces barium, krypton, two or three neutrons and release of energy due to losses of mass. This process is shown in fig 3.4.

❖ The immediate products of a fission reaction, such as Ba^{137} and Kr^{97} are called fission fragments. Both the products are called fission products.

7.With the help of a neat sketch show all important parts of nuclear reactor. Describe briefly the functions of each part.(April/May 2010)(Nov/Dec 2011) (Nov/Dec 2012). Or Describe the general components of nuclear reactor.(May/June 15)or Explain with neat diagram various parts of nuclear power plant and mention function of each part.(Nov/dec 15) Explain with neat diagram various components of nuclear reactor with layout of power plant.(May/ June 17).(APR/MAY 2018)

The main components of nuclear power plant are as

Nuclear reactor

Heat exchanger or steam generator

Steam turbine

Condenser

Electric generator

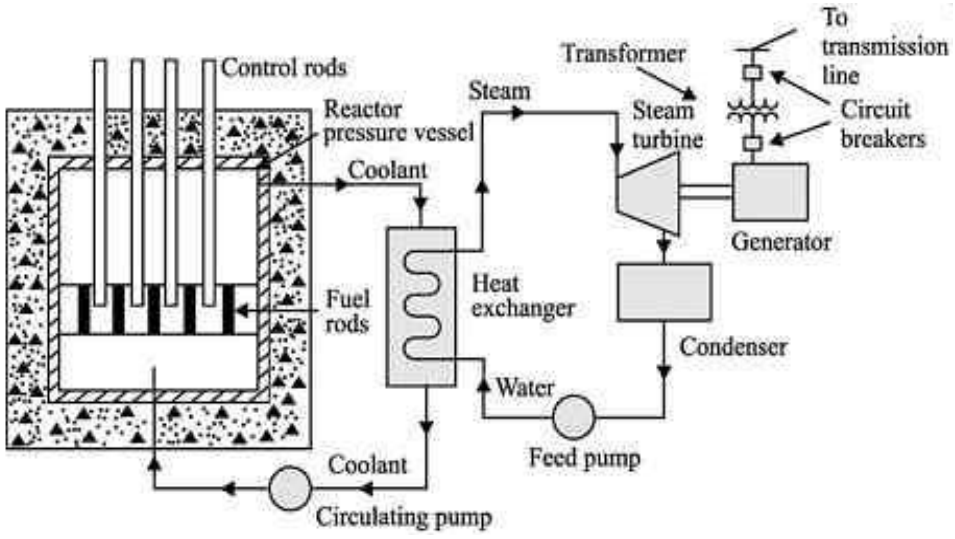


Fig: Nuclear power plant

In nuclear power plant, the reactor function is similar to the furnace of steam power plant. It contains pressure vessel, fuel rods, moderator and shielding. The fuel elements are inserted in the reactor core. The control rods are introduced and positioned in the core to control the chain reaction. Heavy water in the rector acts as a moderator as well as a coolant.

The heat liberated n the reactor by nuclear fission of the fuel is taken up by the coolant circulating through the reactor core. Hot coolant coming out of the reactor core is then circulated though the tubes of a steam generator to generate e steam. The water coming out of

the heat exchanger is circulated by the pump to maintain the pressure in the circuit in the rage of 100 bar to 130 bar.

The steam expands in the steam turbine for producing mechanical work. The steam coming out of the turbine flows into the condenser. The steam turbine in turn runs a electric generator thereby producing electrical energy.

General Components of Nuclear Reactor

- The nuclear reactor may be regarded as a substitute for the boiler fire box steam plant or combustion chamber of a gas-turbine plant.
- The heat produced in the nuclear power plant is by fission whereas in steam and gas turbine plant, the heat is produced by combustion.
- The other cycle of operation and components required are exactly same either as steam plant if steam is generated by using the heat of fission or a gas turbine plant (closed or open type) if gas is heated by using the heat of fission.
- The steam of the gas may be used as working fluid in nuclear power plant.
- The nuclear power plant may be of steam driven turbine of gas driven turbine as per the choice of the fluid.
- The General arrangement of Nuclear power plant with essential components using steam as working fluid is shown in Fig. 7.1

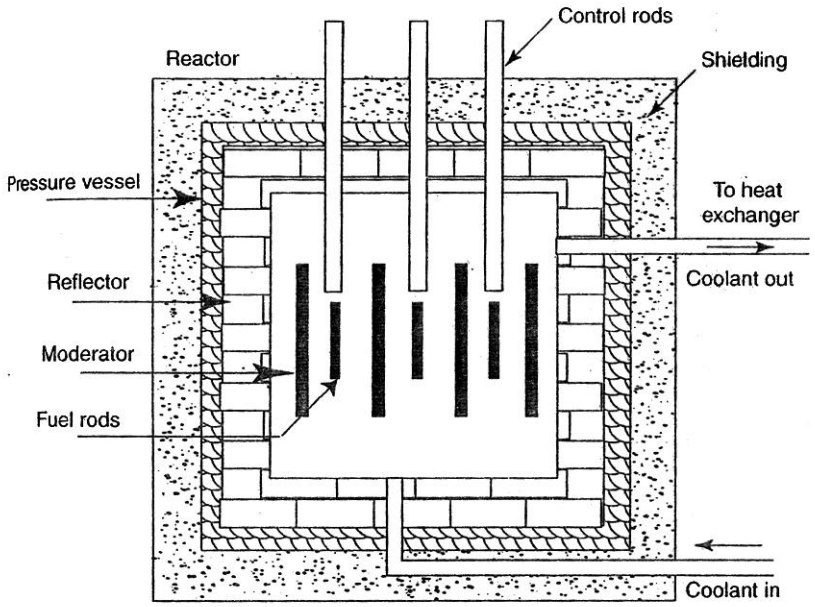


Fig7.1 Components of Nuclear Reactor.

1. **Fuel.**

- The nuclear fuels which are generally used in reactors are $_{92}U^{235}$, $_{94}Pu^{239}$ and $_{92}U^{233}$.
- Among the three, the $_{92}U^{235}$ is naturally available upto 0.7% in the uranium ore and remaining is $_{92}U^{238}$.
- The other two fuels $_{94}Pu^{239}$ and $_{92}U^{233}$ are formed in the nuclear reactors during fission process from $92U^{238}$ and $_{90}Th^{232}$ due to the absorption of neutron without fission.

❖ The fuel is shaped and located in the reactor in such a manner that the heat production within the reactor is uniform. The fuel elements are designed taking into account the heat transfer, corrosion and structural strength.

❖ In homogeneous reactors, the fuel and moderator are mixed to form a uniform mixture i, e. uranium and carbon and then it is used in the form of rods or plates in the reactor core.

❖ In heterogeneous reactors, the fuel is used in the form of rods or plates and moderator surrounds the fuel elements. This arrangement is commonly used in most of the reactors.

❖ The fuel rods are clad with aluminium, stainless steel of zirconium to prevent the oxidation of uranium.

❖ The moderator is a material which reduces the kinetic energy of fast neutron (1Mev or 13200 km/sec) to slow neutron (0.25 eV or 2200 m/sec) and this is done in a fraction of second.

❖ The fission chain-reaction in the nuclear reactor is maintained due to slow neutrons when the ordinary uranium is used as fuel. The function of the moderator is to increase the probability of reaction.

❖ The slowing down of neutrons is effectively done by the light elements as H_2, D_2, N_2, O_2, Be as mentioned earlier.

The desirable properties of a good-moderator are listed below:

1. It must be as light as possible, as slowing down action is more effective in elastic collision with light elements.
2. The moderator must be able to slow down the neutrons earliest possible but it must not absorb them (low absorption cross-section).
3. It must have resistance to corrosion as has to work under high pressure and high temperature.
4. It must have good mechanability if the moderator is used in solid form.
5. The moderator must have melting point if it is solid.
6. It should not be decomposed due to the nuclear radiation as well as it must have high chemical stability.
7. It must also have good conductivity as it is one of the essential properties for better heat transfer in the reactor core.
8. The material selected must be cheap and must be available in abundance and in pure from.

2. Reflector.

❖ It is always necessary to conserve the neutrons as much as possible in order to reduce the consumption of fissile material and to keep the size of the reactor small.

❖ The neutrons which are released in fission process can be absorbed by the fuel itself, moderator, coolant or structural materials. Some neutrons may escape from the core without absorption and will be lost for ever.

❖ To reduce the loss of escape, the reactor inner surface is surrounded by a material which reflects the escaping neutrons back in to the cor8e. This material is called reflector.

❖ The required properties of a good reflector are low absorption and high reflection for neutrons, high resistance to oxidation and irradiation as well as high radiation stability.

❖ Many times the material used as moderator is also used as reflector because the moderating materials have good reflecting characteristics. The H_2o, D_2O and carbon are also used as reflectors.

❖ The amount of fissionable material required can be reduced with the use of good reflector.

❖ It is necessary to provide some method of cooling the reflector as it gets heated due to collision of neutrons with its atoms.

3.Cooling System

❖ The coolants are used to carry away heat produced inside the reactor to the heat exchanger.

❖ From the heat exchanger, heat is transferred to another working medium for further utilization of power generation.

The desirable properties for a reactor coolant are:-

1. Low melting point
2. High boiling point
3. Low viscosity
4. Non-corrosiveness
5. Non-toxicity
6. Low parasite capture
7. High chemical and radiation stability
8. High specific heat
9. High density

❖ The various fluids are used as coolant like water (light water or heavy water), gases (helium, CO_2, hydrogen or air), liquid metals such as sodium and organic liquids.

4.Reactor Vessel

❖ The reactor vessel encloses the reactor core, moderator, reflector, shield and control rods.

❖ It is a string walled container to withstand high pressure. At the top of the vessel, holes are provided to insert control rods. At the bottom of the vessel, the reactor core is placed.

5.Biological Shielding

❖ An operating reactor is a powerful source of radiation, since fission and subsequent radioactive decay produce neutrons and gamma rays, both of which are highly penetrating radiations.

❖ A reactor must have special shielding around it to absorb this radiation in order to protect technicians and other reactor personnel in a popular class of research reactors known as "swimming pools"

❖ A modular reactor head shielding system formed from a plurality of flexible pads shaped to interleave with edges of each adjacent to protect workers from radiation exposure in working in the area around the reactor head or when working on the reactor during refuelling of the reactor.

❖ The pads are formed by inserting a pair of blankets secured to one another inside a pair of outer covers which are secured to one another in offset relation to form an interleave or tongue and groove configuration to eliminate radiation paths between pads.

❖ The blankets are formed by quilting lead wool within the blanket covers. Each pad has a hanging plate secured to one end which can be hung from a frame secured to one another such as with straps to insure elimination of radiation paths there between.

❖ Shielding is necessary to protect the walls of the reactor vessel from radiation damage and also protects the operating personnel from exposure to radiation.

❖ Thick layers of lead concrete or steel are provided all around the reactor. These layers absorb the gamma rays, neutrons etc.

A good shielding material should have the following properties.

1. It should absorb α, β and γ radiations efficiently.
2. It should have uniform density.
3. It should not be decomposed by radiation.
4. It should be fire resistant.

Types of shielding:

(i)Radiation shielding

(ii)Neutron shielding

1.Radiation Shield for Nuclear Reactors

❖ A shield for use with nuclear reactor systems is to attenuate radiation resulting from reactor operation.

❖ The shield comprises a container preferably of a thin, flexible or elastic material, which may be in the form of bag, a mattress, a toroidal segment or toroid or the like filled with radiation attenuating liquid

❖ Means are provided in the container for filling and draining the container in place.

❖ Due its flexibility, the shield readily conforms to irregularities in surfaces with which it may be in contact in a shielding position.

❖ Radiation shielding is done in many ways such as lead, Lead glass, Leaded Acryilic Rolling Shields, L-Blocks, Hot Labs.

❖ In addition to this, Beta shielding, Gamma and therapy and Radiology shielding using X-rays are done to protect the nuclear reactors.

8. Explain the following terms: (April/May 2010)

(i)The chain reaction or Explain what is chain reaction in connection with a nuclear reactor (Nov/Dec 2010) (April/May 2012) (Nov/Dec 2012)(Nov/dec15)(May/ June 17).

The Chain Reaction:

❖ During fission process, neutron is absorbed by the nucleus of atom of U^{235} and splits up into two fragments of approximately equal size.

❖ Also about 2.5 neutrons are released and a large amount of energy is produced. The neutrons produced move with very high velocity ($1.5X10^7 m/s$) and fission other nuclei of U^{235}.

❖ Thus, fission process and release of neutrons take place continuously throughout the remaining material. This self-sustaining reaction is known as chain reaction.

Definition:

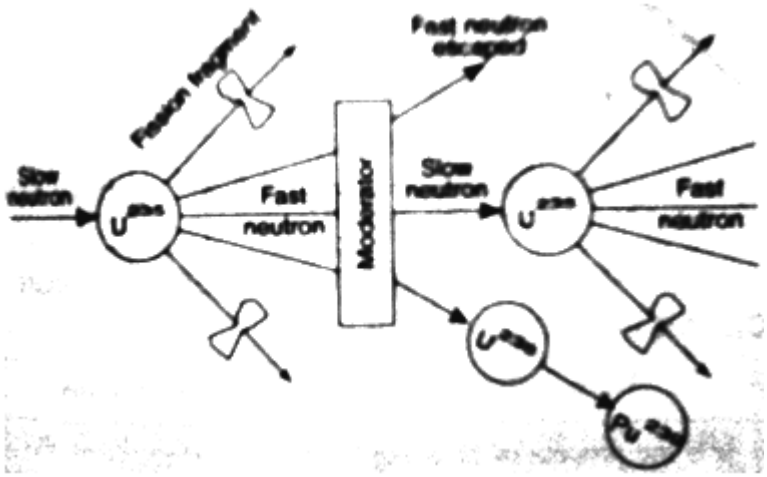
❖ This chain reaction is the process in which the number of neutrons keeps on multiplying rapidly during the fission till whole of the fissionable material is disintegrated.

❖ The chain reaction will become self-sustaining or self-propagating only. At least one fission neutron becomes available for causing fission of another nucleus.

❖ This condition can be conveniently expressed in the form of multiplication factor or reproduction factor of the system.

$$K=\frac{\text{Number neurons in any particular generation}}{}$$

Number neutrons in the preceding generation



❖ For sustaining chain reaction, K should be greater than 1 and if K is less than 1, chain reaction cannot be maintained.

❖ There are two reasons why not all the fission neutrons cause further fission.

1. Absorption of some neutrons causes further fission products, non-fissionable nuclei in the fuel, structural material, moderator and so on.
2. Leakage of neutrons escaping from the core.

For example, about 2.5 neutrons are released in fission of each nuclei of U^{235}. Out of these, one neutron is used to sustain the chain reaction. 0.9 neutrons are absorbed by U^{238} and become fissionable material Pu^{239}.. The remaining 0.6 neutrons are partly absorbed by control rod material, coolant, moderator, and partly escape from the reactor.

9. Write a detailed technical note on Gas cooled reactor. (April/May 2011)

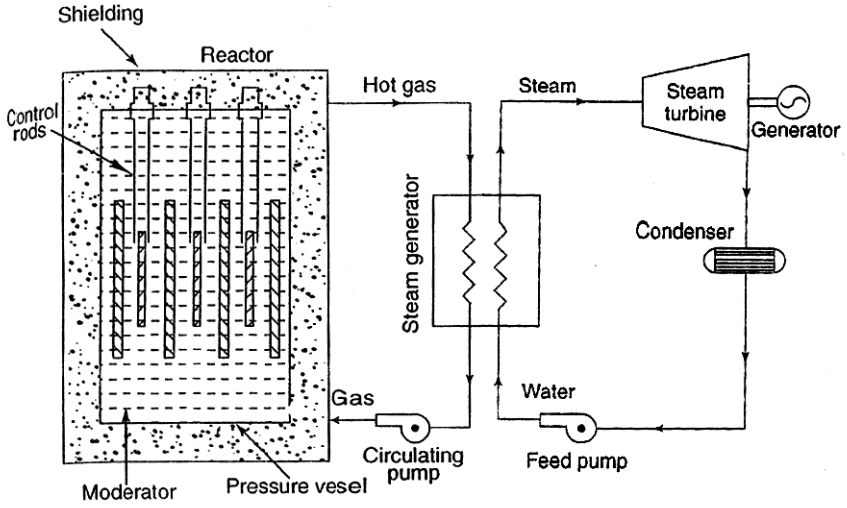


Figure 9.1 Gas cooled reactor

❖ Like other helium-cooled reactors which have operated or are under development, these will be high-temperature units of 850^{o}C, suitable for power generation, thermochemical hydrogen production or other process heat.

❖ For electricity, the gas will directly drive a gas turbine (Brayton cycle) and steam turbine cycle. Fuels would include depleted Uranium and any other fissile or fertile materials.

❖ Spent fuel would be reprocessed on site and all the actinides are recycled to minimise production of long-lived radioactive wastes.

❖ In this reactor, carbon dioxide gas is used to carry away the heat produced due to nuclear fission in the reactor.

❖ The first gas cooled reactor with CO_2 gas as coolant and graphite as moderator were developed in Britain during 1956-69. The fuel was natural Uranium, clad with an alloy of magnesium called *Magnox*. The gas is maintained at a pressure of about 16*bar*.

❖ Various types of GCR have been developed. England developing an advanced gas cooled reactor (AGR system) and Germany and the USA developing helium cooled, graphite moderated systems.

❖ Gas enters the reactor at the bottom. This gas is heated by the heat released due to the fission of fuel and leaves the rector at the top and flows to heat exchanger. In the heat exchanger, hot gas transfers its heat to water which gets converted into steam. The gas is recirculated with the help of gas blowers.

❖ This steam passes through the turbine and expanded to get mechanical work. Exhaust steam from the turbine is condensed with the help of condenser.

Advantages:

1. Fuel processing is simpler than any other reactors.
2. Corrosion by coolant is negligible.
3. Coolant doesn't react with fuel or with other core materials.
4. Coolants will no flash into vapour if primary system is ruptured.
5. Coolant has very low capture cross section.
6. The Uranium carbide and graphite are able to resist high temperatures and hence, the problem of limiting the fuel element temperature is not as series as in other reactors.
7. System can be designated with negative temperature coefficient.
8. It gives better neutron economy due to low parasite absorption.
9. Any fuel can be used, including natural Uranium.
10. Graphic remains stable under irradiation at high temperatures.
11. Coolant is cheap.
12. Ordinary leakage can be tolerated.
13. There is no possibility of explosion in reactor since, the use of CO_2 as coolant completely eliminates this problem.
14. Gas turbine may be employed.

Disadvantages:

1. Fuel loading is more elaborated and costly.
2. The cost of heavy water (D_2O) is high (Rs. 500 per *kg*).
3. Power density is very low (9.7*kW/litre*) and hence, large vessel is required.
4. Large amount of fuel loading is initially required since, the critical mass is high.
5. Very high standard design, manufacture inspection and maintenance are required.
6. Leakage of gas is a major problem, if helium is used instead of CO_2.
7. More power is required for the circulation of coolant when compared to water-cooled reactors.
8. Reactor vessel and heat exchangers large and expensive.
9. Heat transfer efficiency is low.

10. Coolant must be pressurized.
11. Carbon dioxide dissociated above 300 Centigrade.

10. Explain the importance of nuclear waste management (April/May 2011)

❖ Nuclear power is classified as clean energy source because of absence of noxious combustion products and a supply of fuel which will last for centuries when breeder reactors become operational.

❖ The nuclear power generation poses mainly two problems as follows:

(i) The management of radioactive waste, and

(ii) The danger passed in case of accident is very high and long standing.

❖ The radioactive emission during the operation of the power plant is negligible but the emission intensity is very high which comes out from the wastes.

❖ They emit large quantities of gamma-rays which is very danger or for living matters. It is estimated that the radioactive waste coming out of 400MW power plant would be equal to 100 tons of radium daily.

❖ This much of radioactive waste disposed to the atmosphere would kill all the living organisms within the area of about 100 square kilometres.

❖ Therefore. Safe disposal of nuclear waste is a major problem, and of course, very essential too.

❖ There are number of methods developed for the last 25years to dispose off the different types of nuclear waste safely.

Effects of high-level wastes:

❖ It is important to study the effects of high level wastes to biological systems.

❖ The principle effect is the destruction of body cells in the vicinity of the irradiated region due to interaction of the radiation and the tissue.

❖ There are the following three ways through which the interaction between radiation and tissue is manifested.

1.Ionization:

❖ The formation of ion-pair in tissue requires 32.5eV of energy. When a single 1Mev beta-particle is stopped by tissue about 3100 ion-pairs are formed.

❖ If $1cm^2$ area of tissue surface is subjected to a beam of beta-particles/cm^2/sec, about $31x10^6$ ion-pairs are formed in each second.

❖ This absorption results in complete damage of tissues in the body of man or beast or bird.

2.Displacement:

❖ If the energy o the impinging particle is sufficiently high, an atom in the tissue is displace from its normal lattice position with possible adverse effects.

❖ Neutron and gamma-radiation result in atomic displacement.

3.Absorption:

❖ Absorption of neutron by a tissue nucleus results in forming a radioactive nucleus and changes the chemical nature of the nucleus.

❖ This causes malfunctioning of the tissue cell and cell damage causes severe biological effects including genetic modifications.

11. Explain with neat sketch the difference between controlled and uncontrolled nuclear chain reaction.(Nov/Dec 2011) or Controlled Nuclear Chain Reactions

❖ Out of the number of released neutron from nuclear, only one neutron should be strike another uranium nucleus to maintain a sustained controlled nuclear reaction.

❖ If the neutron and uranium nucleus is less than one then the reaction will not be proceed but if it is more than one then it might cause an atomic explosion (uncontrolled).

❖ The amount of free neutrons in the reaction space is controlled by a neutron absorbing element.

❖ In the reactors, control rods are used for the purpose of absorbing the fast moving neutrons.

❖ They are made by strong neutron absorbent material like Boron, Cadmium etc. The released neutrons possess too much of kinetic energy.

❖ In the controlled chain fission reaction of reactor, fuel assemblies are connected and the control rods are lifted slowly to initiate the chain reaction.

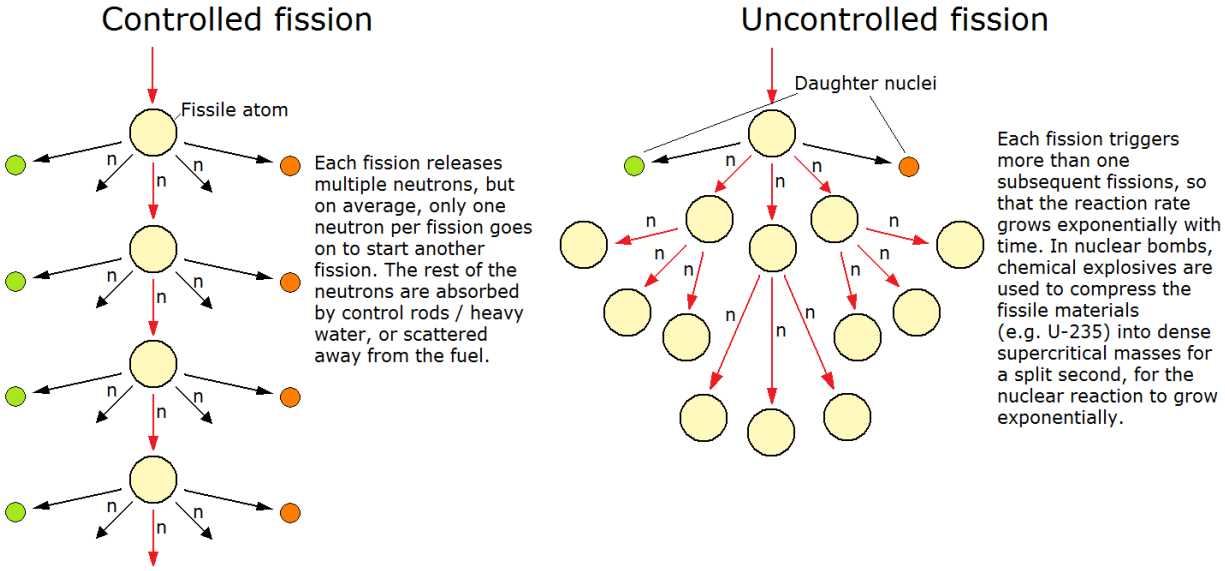
❖ The fissionable atoms of fuel rod allow the reaction to proceed spontaneously in a controlled manner.

❖ As the reaction starts, the uranium-235 nuclei become decreased while fission by-products are produced.

❖ These by-products absorb the produced neutrons. The concentration of fissionable atoms becomes low during this situation which helps in controlling the reaction within.

❖ It helps in making only 3 to 4% of the fuel material.

❖ The use of heavy water helps in slowing down the speed at which the nuclei react with other atoms, while the control rods are used to stop the reaction temporary.



<u>Uncontrolled nuclear chain reaction</u>

❖ The uncontrolled fission reaction takes place in the case of nuclear bomb. Each nuclei produce three neutrons by fission of which two neutrons are utilized in the chain reaction.

❖ Fissionable atom makes more than 80% of fuel in this process. Each nuclei in this uncontrollable manner reaction undergoes fission by two or more compared to two additional reaction.

❖ For example, if one atom proceeds with three other seconds with large amount of heat and energy.

❖ This large amount of released heat energy is the main cause of expansion of the surrounding material. This usually results in nuclear explosion.

(i) Nuclear power plants are used only as base load plants.

(ii) Nuclear reactor needs a moderator material

(iii) Control rods are used in nuclear power reactor.

(i) Nuclear power plants are used only as base load plants.

❖ Nuclear plants are used only as base load plants because any change in load demand requires corresponding change in the output energy.

❖ In the nuclear plants input energy is produced by burning of nuclear fuel core and hence there is always a large time lapse between the change in energy output and input, which is not desirable and hence such power station are used only as load station, supplying constant power.

(ii) Moderator

❖ The process of slowing down the neutrons from high velocity without capturing them is known as moderation.

❖ Moderator is a material which is used to slow down the neutrons from high velocities without capturing them.

❖ The fast moving neutrons are far less effective in causing the fission and try to escape from the reactor.

❖ Thus, the speed of the fast moving neutron is reduced by introducing moderator. Heavy water (D_2O), water (H_2O), Beryllium (Be), Graphite (C) and helium (He) gas are commonly used moderators.

A good moderator should posses the following properties:

- ❖ High thermal conductivity
- ❖ High slowing down power
- ❖ Low parasite captures
- ❖ Lighter
- ❖ High resistance to corrosion
- ❖ Stability under heat and radiation
- ❖ Abundance in pure form
- ❖ High meeting point for solids and low melting point for liquids.
  - ➢ The moderator is characterized by moderating ratio which is the ratio of moderating power to the macroscopic neutron capture coefficient.
  - ➢ If the moderating ratio is high, then the given substance is more suitable for slowing down the neutrons.

(iii) Control Rods

The function of control rod is:

- ❖ To control the rate of fission.
- ❖ To start the nuclear chain reaction when reactor is started from cold.
- ❖ To shut down the reactor under emergency condition.
- ❖ To maintain the chain reaction at a steady state.
- ❖ To prevent the melting of fuel rods.

- Boron, Cadmium and hafnium are mostly used as control rods. These control rods are used to absorb the neutrons thereby reducing the chain reaction.
- The control rods must be able to absorb excess neutrons. The position of these rods is regulated by electronic or electromechanical device.

Control rods should possess the following properties:

- Good stability under heat and radiation
- Adequate heat transfer properties
- Better corrosion resistance
- Sufficient cross-sectional are for the absorption of neutrons.

12. Write a note on nuclear waste disposal? (Nov/Dec 2012)

- Nuclear power is classified as clean energy source because of absence of noxious combustion products and a supply of fuel which will last for centuries when breeder reactor become operational.
- The nuclear power generation poses mainly two problems as follows:

(i)The management of radioactive waste, and

(ii)The danger passed in case of accident is very high and long standing.

- The radioactive emission during the operation of the power plant is negligible but the emission intensity is very high which comes out from the wastes.
- They emit large quantities of gamma-rays which is very danger or for living matters. It is estimated that the radioactive waste coming out of 400MW power plant would be equal to 100 tons of radium daily.
- This much of radioactive waste disposed to the atmosphere would kill all the living organism within the area of about 100 squares kilometers.
- Therefore, safe disposal of nuclear waste is a major problem, and of course, very essential too.
- There are number of methods developed for the last 25 years to dispose off the different types of nuclear waste safely.

13. Explain the various factors to be considered while selecting the site for nuclear plant. (Nov/Dec 2013) (APR/MAY 2018)

1.Proximity to load centre
2.Population distribution
3. Land use
4. Meteorology
5.Geology
6.Hydrology
7.Seismology

(i)Proximity to load centre

- Power plant site can be located to the load center to reduce the cost of power delivered to consumer

(ii)Population distribution

- Since power reactors must be located reasonably close to load centers, the population distribution around the site is a necessary consideration in the evaluation of a nuclear power plant site.

(iii)Land use

- The use to which the land surrounding a nuclear plant site is being put, even though it may not be densely populated, may have an effect on the suitability of the site for a nuclear plant.

(iv)Meteorology

- The radioactivity released from a nuclear plant might be transported to the public, site metrological condition is considered in selecting a nuclear plant site.
- The meteorological variables are normally evaluated are
  (i)Wind-direction frequencies
  (ii)Population distribution
  (iii)Wind velocities
  (iv)Velocity increment
  (v)Frequency and duration of calms.

(v) Geology

- Site geology investigation is very important to determine the bearing capacity of the soil and the types of foundation which must be used for the major portion of the plant.

(vi)Hydrology

- The local hydrology is an important consideration while selecting a site for any power plant.
- Present-day type of nuclear plants require substantially greater quantities of cooling water than do modern fossil steam plants because of their higher turbine heat rates.
- An additional consideration for nuclear plants is given to allow sufficient water flow for the discharge of low level radioactive liquid wastes.

(vii)Seismology

- It is of particular concern in areas of high seismic activity because of the possibility that the forces which can be produced by earthquakes could be sufficient to damage the reactor system and rupture the containment structure.

14. What is meant by uranium enrichment? Describe some methods of Uranium enrichment.(Nov/Dec 2013)

- In most types of reactor, a higher concentration of uranium is used to make Fuel rod. This produced by a process termed enrichment. The enriched uranium containing more than the natural 0.7% U-235

Uranium enrichment can be done by two ways.

1.Gas centrifuge process

2.Gasdiffiusion

- Here the Uranium 235 concentration is increased to 2-4%.There are currently two generic commercial methods employed internationally for enrichment: gaseous diffusion (referred to as *first* generation) and gas centrifuge (*second* generation) which consumes only 2% to 2.5% as much energy as gaseous diffusion.
- Later generation methods will become established because they will be more efficient in terms of the energy input for the same degree of enrichment and the next method of enrichment to be commercialized will be referred to as *third* generation.
- Some work is being done that would use nuclear resonance; however there is no reliable evidence that any nuclear resonance processes have been scaled up to production.

Diffusion techniques

Gaseous diffusion

- Gaseous diffusion is a technology used to produce enriched uranium by forcing gaseous uranium hexafluoride (*hex*) through semi-permeable membranes.
- This produces a slight separation between the molecules containing ^{235}U and ^{238}U.
- Throughout the Cold War, gaseous diffusion played a major role as a uranium enrichment technique, and as of 2008 accounted for about 33% of enriched uranium production, but is now an obsolete technology that is steadily being replaced by the later generations of technology as the diffusion plants reach their ends-of-life.

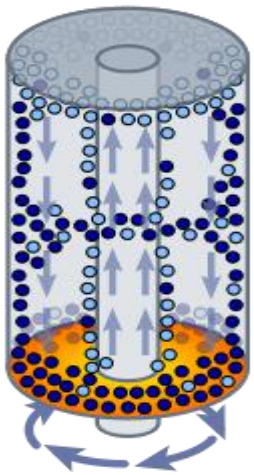
Thermal diffusion

- Thermal diffusion utilizes the transfer of heat across a thin liquid or gas to accomplish isotope separation.
- The process exploits the fact that the lighter ^{235}U gas molecules will diffuse toward a hot surface, and the heavier ^{238}U gas molecules will diffuse toward a cold surface.
- The S-50 plant at Oak Ridge, Tennessee was used during World War II to prepare feed material for the EMIS process. It was abandoned in favor of gaseous diffusion.

Centrifuge techniques

- The gas centrifuge process uses a large number of rotating cylinders in series and parallel formations.
- Each cylinder's rotation creates a strong centrifugal force so that the heavier gas molecules containing ^{238}U move toward the outside of the cylinder and the lighter gas molecules rich in ^{235}U collect closer to the center.
- It requires much less energy to achieve the same separation than the older gaseous diffusion process, which it has largely replaced and so is the current method of choice and is termed *second generation*.
- It has a separation factor per stage of 1.3 relative to gaseous diffusion of 1.005,[9] which translates to about one-fiftieth of the energy requirements. Gas centrifuge techniques produce about 54% of the world's enriched uranium.

Zippe centrifuge



❖ Diagram of the principles of a Zippe-type gas centrifuge with U-238 represented in dark blue and U-235 represented in light blue

❖ The Zippe centrifuge is an improvement on the standard gas centrifuge, the primary difference being the use of heat.

❖ The bottom of the rotating cylinder is heated, producing convection currents that move the ^{235}U up the cylinder, where it can be collected by scoops.

❖ This improved centrifuge design is used commercially by Urenco to produce nuclear fuel and was used by Pakistan in their nuclear weapons program.

Laser techniques

❖ Laser processes promise lower energy inputs, lower capital costs and lower tails assays, hence significant economic advantages.

❖ Several laser processes have been investigated or are under development. Separation of Isotopes by Laser Excitation (SILEX) is well advanced and licensed for commercial operation in 2012.

Atomic vapor laser isotope separation (AVLIS)

❖ *Atomic vapor laser isotope separation* employs specially tuned lasers[11] to separate isotopes of uranium using selective ionization of hyperfine transitions.

❖ The technique uses lasers which are tuned to frequencies that ionize ^{235}U atoms and no others.

❖ The positively charged ^{235}U ions are then attracted to a negatively charged plate and collected.

Molecular laser isotope separation (MLIS)

❖ *Molecular laser isotope separation* uses an infrared laser directed at UF_6, exciting molecules that contain a ^{235}U atom.

❖ A second laser frees a fluorine atom, leaving uranium pentafluoride which then precipitates out of the gas.

15.Explain the characteristics features of BWR .What do you mean by internal and external circulation.(Nov/Dec 14)

❖ Features of BWR The BWR is characterized by two-phase fluid flow (water and steam) in the upper part of the reactor core.

❖ Light water (i.e., common distilled water) is the working fluid used to conduct heat away from the nuclear fuel.

❖ The water around the fuel elements also "thermalizes" neutrons, i.e., reduces their kinetic energy, which is necessary to improve the probability of fission of fissile fuel.

❖ Fissile fuel material, such as the U-235 and Pu-239 isotopes, have large capture cross sections for thermal neutrons.

BWR Design:

1)Generation of steam in a reactor core In contrast to the pressurized water reactors that utilize a primary and secondary loop, in civilian BWRs the steam going to the turbine that powers the electrical generator is produced in the reactor core rather than in steam generators or heat exchangers.

- There is just a single circuit in a civilian BWR in which the water is at lower pressure (about 75 times atmospheric pressure) compared to a PWR so that it boils in the core at about 285°C.
- The reactor is designed to operate with steam comprising 12 to 15% of the volume of the two-phase coolant flow (the "void fraction") in the top part of the core, resulting in less moderation, lower neutron efficiency and lower power density than in the bottom part of the core.
- In comparison, there is no significant boiling allowed in a PWR because of the high pressure maintained in its primary loop (about 158 times atmospheric pressure)

2)Feed water system Inside of a BWR reactor pressure vessel (RPV), feedwater enters through nozzles high on the vessel, well above the top of the nuclear fuel assemblies (these nuclear fuel assemblies constitute the "core") but below the water level.

- The feedwater is pumped into the RPV from the condensers located underneath the low pressure turbines and after going through feedwater heaters that raise its temperature using extraction steam from various turbine stages.

(3) Fluid recirculation in the reactor vessel

- The heating from the core creates a thermal head that assists the recirculation pumps in recirculating the water inside of the RPV.
- A BWR can be designed with no recirculation pumps and rely entirely on the thermal head to recirculate the water inside of the RPV. The forced recirculation head from the recirculation pumps is very useful in controlling power, however.
- The thermal power level is easily varied by simply increasing or decreasing the speed of the recirculation pumps.
- The two phase fluid (water and steam) above the core enters the riser area, which is the upper region contained inside of the shroud. The height of this region may be increased to increase the thermal natural recirculation pumping head. At the top of the riser area is the water separator.
- By swirling the two phase flow in cyclone separators, the steam is separated and rises upwards towards the steam dryer while the water remains behind and flows horizontally out into the downcomer region.
- In the downcomer region, it combines with the feedwater flow and the cycle repeats. The saturated steam that rises above the separator is dried by a chevron dryer structure. The steam then exits the RPV through four main steam lines and goes to the turbine

(4) Reactor power control system Reactor power is controlled via two methods: by inserting or withdrawing control rods and by changing the water flow through the reactor core.

- Positioning (withdrawing or inserting) control rods is the normal method for controlling power when starting up a BWR.
- As control rods are withdrawn, neutron absorption decreases in the control material and increases in the fuel, so reactor power increases. As control rods are inserted, neutron absorption increases in the control material and decreases in the fuel, so reactor power decreases.
- Some early BWRs and the proposed ESBWR designs use only natural circulation with control rod positioning to control power from zero to 100% because they do not have reactor recirculation systems.
- Changing (increasing or decreasing) the flow of water through the core is the normal and convenient method for controlling power. When operating on the so-called "100% rod line," power may be varied from approximately 70% to 100% of rated power by changing the reactor recirculation flow by varying the speed of the recirculation pumps.

- ❖ As flow of water through the core is increased, steam bubbles ("voids") are more quickly removed from the core, the amount of liquid water in the core increases, neutron moderation increases, more neutrons are slowed down to be absorbed by the fuel, and reactor power increases.
- ❖ As flow of 15 water through the core is decreased, steam voids remain longer in the core, the amount of liquid water in the core decreases, neutron moderation decreases, fewer neutrons are slowed down to be absorbed by the fuel, and reactor power decreases.

(5) Steam turbines Steam produced in the reactor core passes through steam separators and dryer plates above the core and then directly to the turbine, which is part of the reactor circuit.

- ❖ Because the water around the core of a reactor is always contaminated with traces of radionuclides, the turbine must be shielded during normal operation, and radiological protection must be provided during maintenance.
- ❖ Most of the radioactivity in the water is very short-lived (mostly N-16, with a 7 second half life), so the turbine hall can be entered soon after the reactor is shut down.

(6) Size of reactor core A modern BWR fuel assembly comprises 74 to 100 fuel rods, and there are up to approximately 800 assemblies in a reactor core, holding up to approximately 140 tonnes of uranium.

- ❖ The number of fuel assemblies in a specific reactor is based on considerations of desired reactor power output, reactor core size and reactor power density.

16.Write about the principle of nuclear energy?List out the various power plants in india.With neat sketch explain any one.(Nov/dec 14) or Write a note on india's three stage nuclear power programme.(may/june 16)

Principle of nuclear energy:

- ❖ A nuclear power plant is a facility at which energy released by the fissioning of atoms is converted to electrical energy under strictly regulated operating conditions.
- ❖ The major processes are the same as those in nonnuclear (conventional) power plants except that the coal or oil fired boiler is replaced by a nuclear reactor.

Various power plants in india:

Power station	Operator	State	Type	Units	Total capacity (MW)
Kaiga	NPCIL	Karnataka	PHWR	220 x 4	880
Kakrapar	NPCIL	Gujarat	PHWR	220 x 2	440
Madras	NPCIL	Tamil Nadu	PHWR	220 x 2	440
Narora	NPCIL	Uttar Pradesh	PHWR	220 x 2	440

Rajasthan	NPCIL	Kota Rajasthan	PHWR	100 x 1 200 x 1 220 x 4	1180
Tarapur	NPCIL	Maharashtra	BWR PHWR	160 x 2 540 x 2	1440
Kudankulam	NPCIL	Tamil Nadu	VVER-1000	1000 x 1	1000[70]

The projects under construction are:

Power station	Operator	State	Type	Units	Total capacity (MW)	Expected Commercial Operation
Madras	Bhavini	Tamil Nadu	PFBR	500 x 1	500	March 2015
Kakrapar Unit 3 and 4	NPCIL	Gujarat	PHWR	700 x 2	1400	Unit 3: June 2015, Unit 4: December 2015
Rajasthan Unit 7 and 8	NPCIL	Rajasthan	PHWR	700 x 2	1400	Unit 7: June 2016, Unit 8: December 2016
Kudankulam Unit 2	NPCIL	Tamil Nadu	VVER-1000	1000 x 1	1000	July 2015

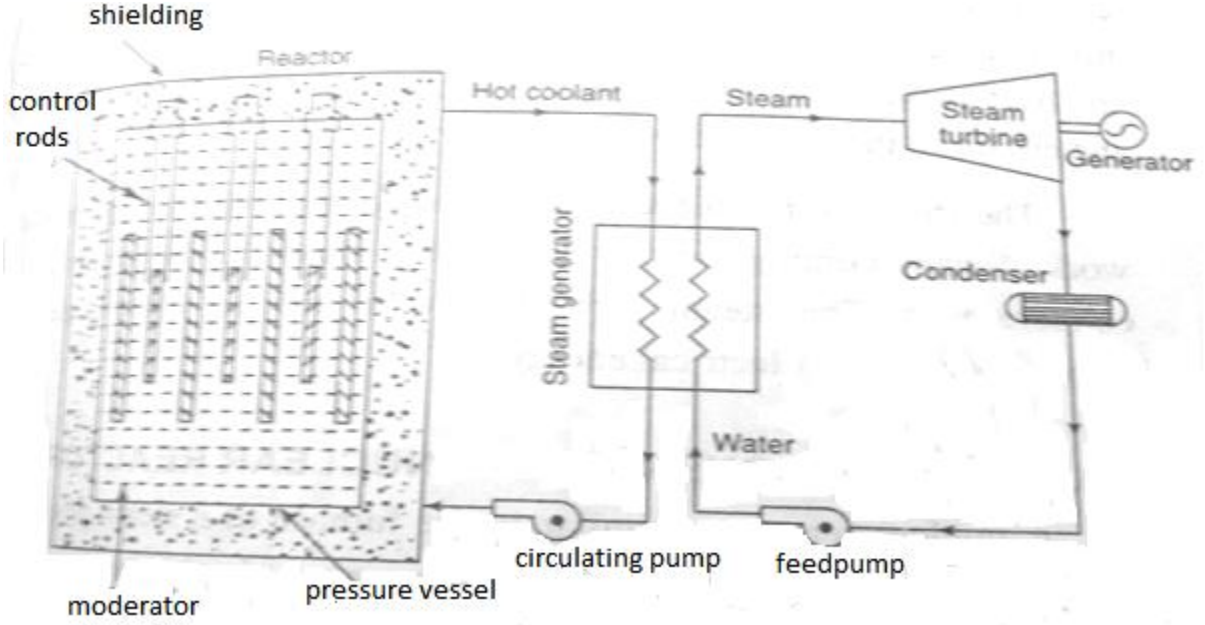
Tarapur Atomic Power Station:

❖ (T.A.P.S.) is located in Tarapur, Maharashtratown of (India). It was initially constructed with two Boiling water reactor (BWR)units of 210 MWe each initially by Bechtel and GE under the 1963 123 Agreement between India, the United States, and the International Atomic Energy Agency (IAEA).

❖ The capacity of units 1 and 2 was reduced to 160 MWe later on due to technical difficulties. Units 1 and 2 were brought online for commercial operation on October 28, 1969.[1]

❖ These were the first of their kind in Asia. More recently, an additional two Pressurised heavy water reactor (PHWR) units of 540 MW each were constructed by L & T and Gammon India, seven months ahead of schedule and well within the original cost estimates.

❖ Unit 3 was brought online for commercial operation on August 18, 2006, and unit 4 on September 12, 2005.



❖ The Boiling water reactors (BWRs) at Tarapur 1 and 2 units are similar to the reactors involved in the Fukushima Daiichi nuclear disaster.[2]

❖ The reactors' age and old design have raised safety concerns and according one local leader, the two reactors have already been in operation for 16 years more than their design lives.

❖ The reactors were originally designed for 40 years at full capacity i.e. 210 MWe. But due to technical problems in the reactor that arose later on, the capacity had to be reduced to 160 MWe.

❖ Hence according to the experts and officials of the plant, their corrected life for unit 1 and 2 is around 23 and 24 years respectively as of March 2012.

❖ Tarapur nuclear plant has received the highest safety awards given to any electricity producing plants in India.

❖ In 2007, Atomic Energy Regulatory Board (AERB) evaluated seismic safety features at Tarapur 1 and 2 and reported many shortfalls, following which NPCIL installed seismic sensors.

❖ In 2011, AERB formed a 10 member committee, consisting of experts from Indian Institutes of Technology (IIT) and India Meteorological Department (IMD), to assess the vulnerability of the Tarapur to earthquakes and tsunamis.[4] A. Gopalakrishnan, former director of AERB, said that Tarapur 1 and 2 reactors are much older than the reactors involved in the Fukushima nuclear accident and argued that they should be immediately decommissioned.

17.Draw a neat sketch on CANDU reactor and explain its working principle and give its advantage and disadvantage?(May/June 14,Nov/dec15)(Nov/Dec 2016) (NOV/DEC 2017)

CANDU reactor :

- ❖ Light water reactors use ordinary water (technically known as light water) as coolant and moderator.
- ❖ They are simpler and cheaper. But they require enriched uranium as their fuel.
- ❖ Natural uranium contains 0.6% of fissionable isotope U235 and 99.3% of fertile Lj23 and to use natural uranium in such reactors it is to be enriched to about 3%, U235 and for this uranium enrichment plant is needed which requires huge investment and high operational expenditure.
- ❖ Heavy water reactors use heavy water as their coolant and moderator. They have the advantage of using natural uranium as their fuel.
- ❖ Such reactors have some operation problem too. Heavy water preparation plants require sufficient investment and leakage of heavy water must be avoided as heavy water is very costly.
- ❖ Heavy water required in primary circuits must be 99% pure and this requires purification plants heavy water should not absorb moisture as by absorbing moisture it gets degraded.

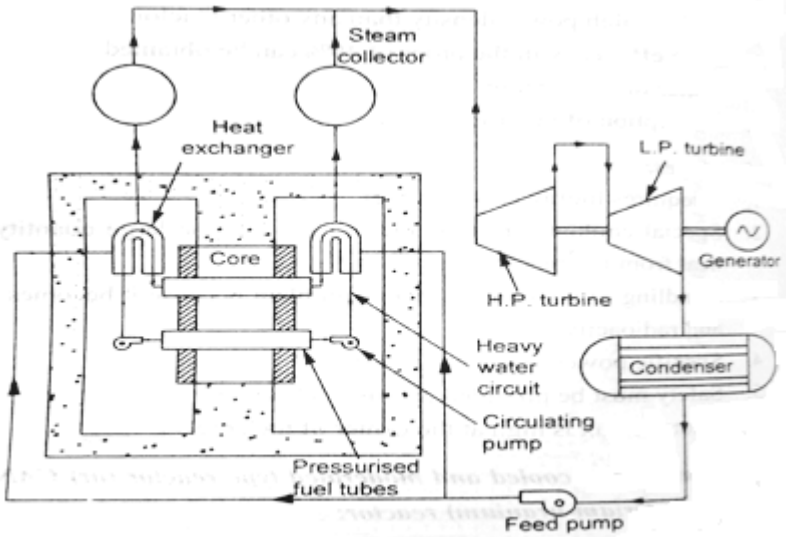


Fig. 3.11. CANDU reactor

❖ In order to have sufficient quantity of heavy water required for nuclear power plants, the work is fast progressing in our country on four heavy water plant.

❖ These plants are situated at Kotah (100 tonnes per year), Baroda (67.2 tonnes), Tuticorin (71.3 tonnes) and Talcher (67.2 tonnes per year).

❖ These plants will give our country an installed heavy water production capacity of about 300 tonnes per year.

❖ Importance of Heavy Water The nuclear power plants of Kota in Rajasthan, Kalpakkam in Tamil Nadu and Narora in U.P. use heavy water as coolant and moderator.

❖ All these projects have CANDU reactors using natural uranium as fuel and heavy water as moderator.

❖ After this enriched uranium natural water reactor at Tarapur, the CANDU reactors are the second generation of reactors in India's nuclear power programme.

❖ The CANDU reactor will produce plutonium which will be the core fuel for fast breeder reactor. In fact in breeder reactor heavy water is used as moderator.

❖ A CANDU reactor of 200 mW capacity requires about 220 tonnes of heavy water in the initial stages and about 18 to 24 tonnes each year subsequently.

❖ Therefore, about one thousand tonnes of heavy water will be required to start the different nuclear power stations using heavy water. The total capacity of different heavy water plants will be about 300 tonnes per year if all the heavy water plant under construction start production.

❖ It is expected that heavy water from domestic production will be available from Madras and Narora atomic power plants.

❖ The management of the heavy water system is a highly complicated affair and requires utmost caution. Heavy water is present in ordinary water in the ratio 1 : 6000. One of the methods of obtaining heavy water is electrolysis of ordinary water.

ADVANTAGES :

The various advantages of a nuclear power plant are as follows:

1.There is no need of enriched fuel.
2.There is no control rods.
3. There is increased reliability of operation.
4. Nuclear power plants are not effected by adverse weather conditions.
5. Nuclear power plants are well suited to meet large power demands. 6.They give better performanceat higher load factors (80 to 90%).

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DISADVANTAGES

1.Heavy water is costly.
2.Leakage of water is amajor problem.
3.Low power density.
4.Initial cost of nuclear power plant is higher as compared to hydro or steam power plant.
5. Nuclear power plants are not well suited for varying load conditions.
6. Maintenance cost of the plant is high.
7. It requires trained personnel to handle nuclear power plants.

UNIVERSITY QUESTIONS

PART-A

1. What is the function of moderator and reflector used in nuclear power plant?.(Nov/Dec 2012) (Refer page no :04)
2. Indicate the types of nuclear fission reactor power plants operating in india. (Anna Univ. May/June 2006) (Refer page no :04)
3. Give the few details about the atomic power station currently operating in Tamilnadu. (May/June 2006) (Refer page no :04)
4. What are the advantages and disadvantages of nuclear power plant.(Nov/Dec 2005) (Refer page no :04)
5. Define-Nuclear fission? (April/May 2011), (May/June 2012) (Refer page no :05)
6. Define- Nuclear fusion?.(April/May 2012) (Refer page no :05)
7. Define Demand for electricity.(Nov/Dec 2013) (Refer page no :06)
8. What are isotopes?.(Nov/Dec 2013) (Refer page no :06)

9. What is an LMFBR? Why is a liquid metal the preferred coolant in a fast breeder reactor? (May/June 2013) (Refer page no :06)

10. What do you mean by mass defect? (May/June 2013) (Refer page no :07)

11. Name the different types of fuels used in nuclear reactors.(Nov/Dec 2012) (Refer page no :07)

12. What is a purpose of a moderator in a nuclear reactor? (Nov/Dec 2012) (Refer page no:07)

13. What are the requirements of fission process?(April/May 2010) (Refer page no :10)

14. What are the essential components of a nuclear reactor?(April/May 2010)
(Refer page no:11)

15. Distinguish between PHWR and LMFBR (April/May 2011)
(Refer page no:11)

16. What is known as binding energy? (Nov/Dec 2011) (Refer page no :11)

17. What is the function of pressurizer in pressurized water reactor? (Nov/Dec 2011) (Refer page no :12)

18. Name the three moderators commonly used in nuclear power reactor. (April/May 2012) (Refer page no:12)

19.Define-Nuclear fission? (April/May 2011),(May/June 2012),(Nov/Dec14)(pg.no:5)

20. What is a purpose of a moderator in a nuclear reactor? (Nov/Dec 2012) or What do you understand by moderation?Why it is essential?(May/june 15) (pg.no:7)

21. What is meant by Radioactivity or radioactive decay?(Nov/dec14) (pg.no:7)

22.Compare nuclear fission with nuclear fusion?(May/june 14) (pg.no:12)

23.What are the desirable properties of good moderators?(May/june 14) (pg.no:12)

24.Distinguish between fertile and fissile material?(May/june 15) (pg.no:12)

25.Why shielding is necessary in nuclear power plants? (Nov/Dec 16)

26.What is critical mass of nuclear fuel? (Nov/Dec 16)

PART B

1.Briefly explain the pressurized water reactor (PWR) with neat sketch.(May/June 2013) (Nov/Dec 2011) (Refer page no :13)

2.Explain boiling water reactor (BWR)with neat sketch. Give its
Advantage and disadvantage. (May/June 2013) (April/May 2011) (Nov/Dec 2010) (Refer page no :15)

3.Briefly explain the Fast Breeder Reactor(FBR) with a neat sketch.(Nov/Dec 2010) (Refer page no :16)

4.What are the advantages and disadvantages of nuclear power plants compared to other conventional power plants.(Anna Univ.April/ May 2012) (Nov/Dec 2010) (Refer page no :17)

5.Explain different methods for nuclear waste disposal with necessary sketch.(May/June 2013) (Refer page no :18)

6.What is known as nuclear fission? What are the essential requirements to cause nuclear fission.(Nov/Dec 2011) (Refer page no :20)

7.With the help of a neat sketch show all important parts of nuclear reactor. Describe briefly the functions of each part.(April/May 2010) (Nov/Dec 2011) (Nov/Dec 2012). 8.Explain the following terms: (April/May 2010(i) Fission of nuclear fuel (Nov/Dec 2012) (ii) Distribution of

nuclear energy (iii)The chain reaction or Explain what is chain reaction in connection with a nuclear reactor (Nov/Dec 2010) (April/May 2012) (Nov/Dec 2012) (Refer page no :26)

9. Write a detailed technical note on Gas cooled reactor. (April/May 2011)
(Refer page no:27)

10. Explain the importance of nuclear waste management (April/May 2011)

11. Explain with neat sketch the difference between controlled and uncontrolled nuclear chain reaction.(Nov/Dec 2011) (Refer page no :29)

12. Discuss why? (April/May 2012)

(i) Nuclear power plants are used only as base load plants.

(ii) Nuclear reactor needs a moderator material

(iii) Control rods are used in nuclear power reactor. (Refer page no :30)

13. Explain the various factors to be considered while selecting the site for nuclear plant. (Nov/Dec 2013) (Refer page no:34)

14. What is meant by uranium enrichment? Describe some methods of Uranium enrichment. (Nov/Dec 2013) (Refer page no:35)

15.Draw the diagram of PWR and BWR and explain advantages and disadvantages .What are the condition which prefer PWR over BWR and viceversa?(May/June 15) (pg.no:13)

16.With the help of neat sketch ,explain the working of boiling water reactor and discuss its advantage and disadvantage?(May/June 14) (pg.no:15)

17. With the help of a neat sketch show all important parts of nuclear reactor. Describe briefly the functions of each part.(April/May 2010) (Nov/Dec 2011) (Nov/Dec 2012). Or Describe the general components of nuclear reactor.(May/June 15) (pg.no:22)

18.Explain the characteristics features of BWR .What do you mean by internal and external circulation.(Nov/Dec 14) (pg.no:39)

19.Draw a neat sketch on CANDU reactor and explain its working principle and give its advantage and disadvantage?(May/June 14) (pg.no:44)

20.Write about the principle of nuclear energy?List out the various power plants in india.With neat sketch explain any one. (Nov/dec 14) (pg.no:41)

PART A

1. What is the use of surge tank? (May/June 2012) or What are the function of surge tank in hydro plants?(may/june 16)

- ❖ The surge tank is used to provide better regulation of water pressure in the system. The surge tank controls the water when the load on the turbine decreases and supplies water when the load on the turbine increases.
- ❖ Thus, surge tank controls the pressure variations resulting from the rapid changes in water flow in penstock and hence prevents water hammer.

2.List the classification of hydro electric power plant?

The classification of hydro electric plants based upon :

(a) Quantity of water available (b) Available head (c) Nature of load

(a)Quantity of water available: (i) Run-off river plants with outpondage

(ii) Run-off river plants with pondage

(iii) Reservoir Plants

(b) Available head: (i) Low-Head (less than 30 meters) Hydro electric plants

(ii) Medium-head(30 meters - 300 meters) hydro electric plants

(iii) High-head hydro electric plants

(c) Nature of load (i)Base load plants

(ii) Peak load plants

3. What is spillway? (May/June 17)

❖ Spillway is like a safety valve of the dam. It discharges major flood without damaging the dam. It keeps the reservoir level below the maximum level allowed.

4. Differentiate pelton wheel turbine and Francis turbine. [APR-05]

Pelton wheel turbine	**Francis turbine**
It is easier to regulate pelton wheel	It is difficult to regulate
Comparatively low operating efficiency	Operating efficiency specially between half and full load are better.
Running speed is comparatively less	Running speed of Francis turbine is more than Pelton wheel
Parts are easily accessible and therefore it is easier to repair them	Parts are not easily accessible
Dimension of pelton wheel turbine are higher than Francis turbine	Dimension of Francis turbine are less than pelton wheel
Pelton wheels has to be installed above the maximum tail race which causes loss of head	Francis turbine utilises full available head by using draft tube

5. Write about prime movers?

❖ Prime mover converts the kinetic energy of water into mechanical energy to produce electrical energy. Pelton wheel, turbine, Francis turbine, Kaplan turbine and Propeller turbine are prime movers used in hydraulic power plants.

6. What is the main purpose of the dam?(Nov/Dec 2012)

- The main purpose of the dam is to increase the height of water level and also to increase the working head of the hydraulic power plant.
- It develops an artificial reservoir with desired capacity to store the water up to the required level. It creates the working head of water and increases the same for power generation.

7. What is hydraulic turbine?

- Hydraulic turbine is the machine which converts the energy of flowing water into mechanical energy.

8. What is hydrograph? [MAY/JUN 2013]

- Hydrographs are charts that display the change of a hydrologic variable over time. Here are several examples from the US Geological Survey's gaging station on the Tioga River near Mansfield, Pennsylvania.
- Although these examples are from a stream, hydrographs can also be made for lakes, water wells, springs and other bodies of water.

9. Write short notes on Micro Hydel plant? [MAY/JUN 2012],[MAY/JUNE 2007]

- Micro hydro defined as a plant between 10kw and 200 Kw is perhaps the most nature of the modern small scale decentralised energy supply technologies used in developing countries.
- Hydropower is energy from water sources such as the Ocean Rivers and waterfalls micro-hydro means which can apply to sites ranging from a tiny scheme to electrify a single home to a few hundred kilowatts for selling into the national grid.

10. On what basis hydraulic turbines are selected? [NOV/DEC 2012]

- Initial turbine selection is usually based on the ratio of design variables known as the power specific speed. In U.S. design practice this is given by

$$N = \frac{nP^{1/2}}{H^{5/4}},$$

11. Why surge tank important in hydro power plant?[APR/MAY 2010]

- A surge tank is a small reservoir or tank in which the water level rises or falls to reduce.

12. Write the formula to calculate the hydraulic power produced by a hydro turbine: The hydraulic power is given by the formula:

P=GpQH

- Where P is the hydraulic energy in watts
- G is acceleration due to gravity (9.81 M/s2) P is water density
- Q is the flow or discharge
- H is the height of fall of water or head in meter.

13. List any four advantages and disadvantages of hydro power: (May/June 2013)

Advantages

1. Water source is perennially available
2. Running cost is very low

3. Non-polluting
4. Power generation can be switched on and off in a very short period.

Disadvantages

1. High capital investment and low rate of return
2. Gestation period is very large
3. Power generation depends on availability of water
4. Transmission cost and losses are high

14. List the factors to be considered for the selection of site for hydro power plant. Or What are the different factors to be considered while selecting the site for hydro electric power plant?(may/june 15)

1. Availability of water and water head
2. Accessibility of site
3. Water storage capacity
4. Distance from the load center
5. Type of land

15. List the classification of dams:

1. Based on their functions:
   (a) Storage dams
   (b) Diversion dams
   (c) Detention dams
2. Based on their shape:
   (a) Trapezoidal dams
   (b) Arch dams
3. Based on the materials of construction:
   (a)Earth dams
   (b) Rock pieces dams
   (c) Stone masonry dams
   (d) Concrete dams
   (e) RCC dams
   (f) Timber and Rubber dams
4. Based on hydraulic design:
   (a) Overflow type dam
   (b) Non-overflow type dam
5. Based on structural Design:
   (a) Gravity dam
   (b) Arch dam
   (c) Buttresses dam

16. What is a surge tank? Or What for surge tank is provided in the hydel plant? (May/June 2012) or what is surge tank? Why it is important in hydro power plants?(nov/dec 14)

❖ A surge tank is a small reservoir in which the water level rises or falls to reduce the pressure swings during opening and closing of inlet valve.

❖ The surge tank is not required for run off plants and medium head plants.

17. What is the function of Draft tube? (May/June 2012)

❖ The draft tube allows the turbine to be set above the tail race to facilitate inspection and maintenance.

❖ It also regains the major portion of the kinetic energy at the runner outlet by diffuser action. The draft tube can be a straight conical tube or an allow tube.

18. List the types of hydro power plants based on availability of head?

1. High head power plant (head>100m)
2. Medium head power plant (30m-100m)
3. Low head power plant (head<30m)

19. List the advantages of impulse turbine:

1. Greater tolerance of sand and other particles in the water
2. Better access to working parts
3. No pressure seals around the shaft
4. Easier to fabricate and maintain
5. Better part-flow efficiency

20. What are the essential elements of hydro power plant?

1. Catchment area
2. Reservation
3. Dam
4. Surge tanks
5. Draft tubes
6. Power house
7. Switched for transmission of power

21. What are mini and micro Hydro plants? (may/june 15)

❖ The mini power plants operate with 5m-20m head and produce about 1 MW to 5 MW of power.

❖ The micro power plants require a head less than 5m and produce 0.1 MW to 1 MW.

22. Define turbines and its types.(nov/dec 14)

❖ A turbine converts energy in the form of falling water into rotating shaft power.

❖ The selection of best turbine for any particular site depends on the site characteristics.

TYPES:(i) Reaction turbines

- High head- Francis
- Medium head- Propeller
- Low head- Kaplan

(ii) Impulse turbine

23. What is pelton turbine?

❖ A pelton turbine consists of a set of specially spread buckets mounted on a periphery of a circular disc.

❖ It is turned by jets of water which are discharged from one or more nozzles.

24. What is meant by reaction turbines and propeller turbine?

❖ Francis turbine and propeller turbines are the reaction turbines. The reaction turbines rotate faster than impulse turbine.

❖ The basic propeller turbine consists of a propeller. Inside it consist of a continuation of the penstock tube.

25. What is meant by Kaplan turbine?

❖ The pitch of the propeller blades together with wicket gate adjustment enables reasonable efficiency to be maintained under part flow conditions. Such turbines are called as Kaplan turbines.

26. Explain impulse turbine in terms of heads?

❖ High head- pelton Turbine
❖ Medium head- Multi jet pelton turbine
❖ Low head- cross flow

27. For which hydro projects are developed. (Nov/Dec 2013)

1. Water is renewable source of energy and available at free of cost.
2. No Pollution due to absence of fuel and ash handling.
3. Plant can be started and stopped very quickly. Operating cost and running cost is considerably lower than that of thermal power plants.
4. I t has no stand by losses.

28. What is meant by water hammer.(may/june14)

❖ Conversely, when the load on the generator is increased, vaccum builds up in the penstock..This phenomenon results in a hammering action called water hammer.

29. Classify the hydro-electric turbines with respect to high medium and low head.(Nov/Dec 2012).

	High head	Medium Head	Low head
Impulse turbine	PeltonTurgo	Cross-flow multi-jet peltonTurgo	Cross-flow
Reaction Turbine	Francis	Propeller	Kaplan

30. What is draft tube? (Anna Univ. April 2005)

❖ The draft tube allows the turbine to be set above the tail race to facilitate inspection and maintenance.

❖ It also regains the major portion of the kinetic energy at the runner outlet by diffuses action. The draft tube can be a straight conical tube or an hollow tube.

31. What are three main factors for power output of hydroelectric plant?(Anna Univ.Apil 2005)

(i)Load Factor
(ii)Demand Factor
(iii)Utilization factor.

32 . What is significance of specific speed of hydraulic turbines?(Anna Univ. June 2009)?

❖ Specific speed plays an important role in the selection of a type of turbine.By knowing the specific speed of the turbine, the performance of the tube can also be predicted.

33. Define Unit speed of turbine (Anna Univ. November 2003)

The speed of turbine when working under a unit head.

34. On What factors does the selection of a water turbine for hydel plants depend upon? (May/June 2012)

- ❖ Rotational Speed of the Turbine.
- ❖ Specific Speed.
- ❖ Maximum Efficiency.
- ❖ Part Load Efficiency.
- ❖ Working Head Of The Water
- ❖ Runaway Speed
- ❖ Overall Cost Of The Plant
- ❖ Size Of The Turbine
- ❖ Type Of Water Available

35. Define run-off.

❖ **Runoff** can be described as the part of the water cycle that flows over land as surface water instead of being absorbed into groundwater or evaporating.

36.Differntiate storage with pondage.(may/june 14)

Storage	**Pondage**
The purpose of storage providing storage is to make more water available during deficient flow types.	The purpose of pondage is required near the power plant in order to meet hourly changes in power demand
Storage capacity should be determined with the help of the mass curve	Amount of storage is determined with the help of chronological load curve

37.What is the principle of solar generation?

❖ Solar energy the energy produced in the sun and collected on the earth. Energy from sun in the form of heat and light is harnessed.

❖ Solar heating system uses the heat energy and solar electric system uses light energy (photo voltic cell) to generate electrical energy

38. List the various types of solar energy collectors. Or what are the types of solar collector.(Nov/Dec 14)

1. Stationary collectors (or) Non- concentrating
   - (a) Flat plate collectors
   - (b) Compound parabolic collectors
   - (c) Evacuated tube collectors
2. Sun tracking concentrating collector
   - (a) Single axis tracking
   - (b) Two-axis tracking

39.List the advantages of solar Energy.

1. Solar energy is free from pollution

2. They collect solar energy optically and transfer it to a single receiver, thus minimizing thermal-energy transport requirements

3. They typically achieve concentration ratios of 300 to 1500 and so are highly efficient both in collecting energy and converting it to electricity.

4. The plant requires little maintenance or help after setup

5. It is economical

40.Four disadvantages of solar energy.

6. Available in day time only
7. Need storage facilities
8. It needs a backup power plant
9. Keeping back up plants hot includes an energy cost which includes coal burning
3. Improper sealing
4. Parasitic power consumption by exhaust compressor

41. What is a solar cell? (May/June 2012, Dec 12)

- A solar cell is a device that directly converts the energy in light into electrical energy through the process of photovoltaic effect.

42.What are the types of collectors used in solar power generation? Or What are the types of solar collector? (Nov/dec 14)

Types of collectors

a) Flat plate collectors(60°C)
b) Focusing or concentrating collectors
c) Cylindrical parabolic concentrator (100-200°C)
d) Paraboloids, Mirror Arrays(<200°C)

43.List the various components of wind energy system.

1. Rotor
2. Gearbox
3. Enclosure
4. Tailvane

44.What are the two basic design of turbines?

Vertical axis (or) Egg beater style
Horizontal axis (propeller style) machines

45.List any four advantages of wind turbine. Or Mention the various advantage of wind power.(Nov/dec 15)

Advantages

Inexhaustible fuel source
No pollution
Excellent supplement to other renewable source
Its free

Disadvantages

Low energy production
Expensive maintenance

46.Mention the factors which determine the power in wind. (April/May-2007)or How are wind formed? (APR/MAY 2018)

a) The area of the wind mill being swept by the wind.
b) The cube of the wind speed
c) The air density – which varies with altitude.

47.What are the components of tidal power station?

Barrage
Turbines
Sluices
Embankments

48.List any four advantages and disadvantage of tidal power generation. Or What are the limitation of tidal power plant. .(Nov/dec 15)

Advantages

Renewable and sustainable energy
No liquid or solid pollution
Little visual impact
Reduces dependence upon fossil fuels

Disadvantages

Orientation problem
Requires storage devices
Available at a lower rating and time
High capital cost

49. What are the main parts of geothermal power plant?

1. Production well
2. Vaporizer
3. Circulating pump
4. Expansion turbine
5. Generator
6. Condenser
7. Transformer

50.What are the classifications of geothermal energy conversion system? (NOV/DEC 2017)

1. Single cycle geothermal power plant
2. Binary cycle power plant

51.What are the applications of geothermal energy?

Generation of electric power
Space heating for building
Industrial process heat

52.What are the advantages and disadvantage of geothermal energy?

Advantages

Cheaper
Versatile in its use
Delivers greater amount of energy

Disadvantages

Drilling operation is noisy

It needs large areas of exploitation of geothermal energy
Low overall power production efficiency.

53.What is the principle of GEO THERMAL power generation? (AUApril/May 2010)

❖ Residual thermal energy is left over in fluids in deep reservoirs within the earth's crest left over by planets origin.

❖ Hot natural supply of water which can produce steam by the hot underground magma is exhausted and processed.

54.What is tide?

❖ TIDE is a periodical rise and fall of the water level of sea which are carried by the action of the sun and moon on the water of the earth.

❖ The main feature of the tidal cycle is the difference in water surface elevations at the high tide end, the tidal energy can be converted into electrical energy by means of a generator.

55. What is the principle of tidal power generation? Or What is tide range? (NOV/DEC 2017)

❖ Tidal movements of tides in seas are due to difference in water levels caused by (1) gravitational forces between the Sun, moon and the earth and (2) rotation of the moon and earth.

❖ The kinetic energy of moving tides and the potential energy difference between the high tides and the low tides can be converted into electrical energy.

56.What are the factors to be considered for suitable site selection of tidal power plant?

Various factors that are needed to be considered for the location of tidal power plant are:

- ❖ The location of the plant must be nearer to the ocean.
- ❖ Site selection for the plant should be in such a way that the tidal range of ocean is large (generally greater than 7 m).
- ❖ The geographic features of the plant must be encloses of large areas with short dams i.e. a narrow entrance to the inlet and plenty of water moving through it at each tide.
- ❖ The sluice gates of dam should allow water to or from the basins.

57. Define the term gust in a wind energy system. (NOV/DEC-2012)

❖ It is a sudden, brief increase in speed of the wind. According to U.S. weather observing practice, gusts are reported when the peak wind speed reaches at least 16 knots and the variation in wind speed between the peaks and lulls is at least 9 knots. The duration of a gust is usually less than 20 seconds.

58. What are the merits and demerits of tidal power generation?

The advantages of tidal power are

a) It is free from the problems of uprooting the people and disturbing the ecology balance.

b) It is everlasting and is not influenced by the charging mood of the nature such as failure of the monsoon.

c) No extra submerging of land is involved.

❖ The major drawback of tidal power plants is their uneven operation.

❖ Variations in the tidal energy available through the lunar day and lunar month.

59. Define Co-efficient of performance with respect to wind mill. (April/May-2009)

❖ The power actually captured by the wind turbine rotor, P_R, is some fraction of the available power, defined by the coefficient of performance, C_p, which is essentially a type

of power conversion efficiency:

$$C_p = P_R/P$$

❖ The maximum theoretical value of the coefficient of performance is 0.593

60. What is fuel cell? State the advantages. (May/June 17) (APR/MAY 2018)

❖ A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent.

❖ Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols like methanol are sometimes used.

Advantages of Fuel Cells

1. Conversion efficiencies are very high.
2. Require little attention and less maintenance.
3. Can be installed near the use point, thus reducing electrical transmission requirements and accompanying losses.
4. Fuel cell does not make any noise.
5. A little time is needed to go into operation.

61.State the application of solar thermal system.

1. It gives very high temperatures. High temperatures are suitable for electricity generation using conventional methods, such as steam turbine or some direct high temperature chemical reaction.
2. A larger area can be covered by using relatively inexpensive mirrors rather than using expensive solar cells.
3. Concentrated light can be redirected to a suitable location via optical fiber cable. For example illuminating buildings, like here (Hybrid Solar Lighting).
4. Heat storage for power production during cloudy and overnight conditions can be accomplished, often by underground tank storage of heated fluids. Molten salts have been used to good effect.

62.What are the different sources of geothermal energy? (Dec 12, May 13)

i. Hydrothermal convective systems
ii. Geo – pressure resources
iii. Petro – thermal or hot dry rocks
iv. Magma resources
v. Volcanoes

63.What is the principle of a thermoelectric power generator? (May/June 2012)

❖ It is similar to a thermocouple with the difference that the thermo – elements are made up of semi conductors P and N, heat is given to the hot junction and the heat is removed from the cold junction.

64.What do you understand by zero energy houses? (May 13)

❖ A zero – energy building is also known as a zero net energy (ZNE) building or net – zero energy building (NZEB). It refers a building with zero net energy consumption and zero carbon emissions annually.

65. Define law of conservation of energy. (Dec 13)

❖ This law suggests that energy can be transferred from one system to another in many forms. Also, it cannot be destroyed or created.

66.Give example of geothermal resources?(Nov/dec 14)

1.Puga Valley of the LAdakh region in Jammu and Kashmir.
2.Cambay region of Gujarat and Maharastra.
3.Tattapani-Hydro –Geothermal field,Madhyapradesh.

67.Enumerate the factors affecting the suitability of the site for the tidal power plant.(May/june 15)

❖ The volume of water moving around during the tide or the cubature of the tidal flow is an important factor which determines the suitability of a site.

68.What is the principle of OTEC plant?(May/june 14)

❖ The ocean water gets heated up naturally due to solar radiation.The temperature of water near surface is higher than that of deep water.Significance amount of heat can be extracted from ocean thermal gradient principle of thermodynamics.

69. What is biogas? Give the advantages. (Nov/Dec 16)

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH4) and carbon dioxide (CO2) it is a renewable fuel produced from waste treatment.

Advantages:

❖ Pollution free
❖ Improved and stabilized sanitation
❖ Energy storage is in built feature
❖ Reduce waste disposal problems

70. Differentiate Francis turbine and Kaplan turbine. (Nov/Dec 16)

Francis turbine	**Kaplan turbine**
Correct disposition of the guide and moving vanes is obtained at full load only	Correct disposition of the guide and moving vanes is obtained at any load
System may have one or two servomotors depending on the size of the unit.	Two servomotors respective or the size of the unit always do governing
Since the guide vanes are only controlled and high efficiency is obtained.	Both guide and runner vanes are controlled and high efficiency is obtained at partial loads
Servomotors are kept outside the turbine shaft.	Both servomotors are kept inside the hollow shaft of the turbine runner.

PART B –(16 MARKS)

1.Explain layout of hydel power plant (or) With a simple Diagram, explain the essential features of hydro power plant. (Nov/Dec 2013) or Explain the arrangement of the components of the hydro electric power plant with neat sketch.(may/june 14).Draw a schematic diagram of a hydro plant and explain the operation..(Nov/dec 15)(Nov/Dec 2016)(May/ June 17) (APR/MAY 2018)

Hydroelectric power plant

❖ A hydroelectric power plant is aimed at harnessing from water flowing under pressure. In hydroelectric power plant the energy of water is utilized to drive the turbine (or) water power is important only next to the thermal power.

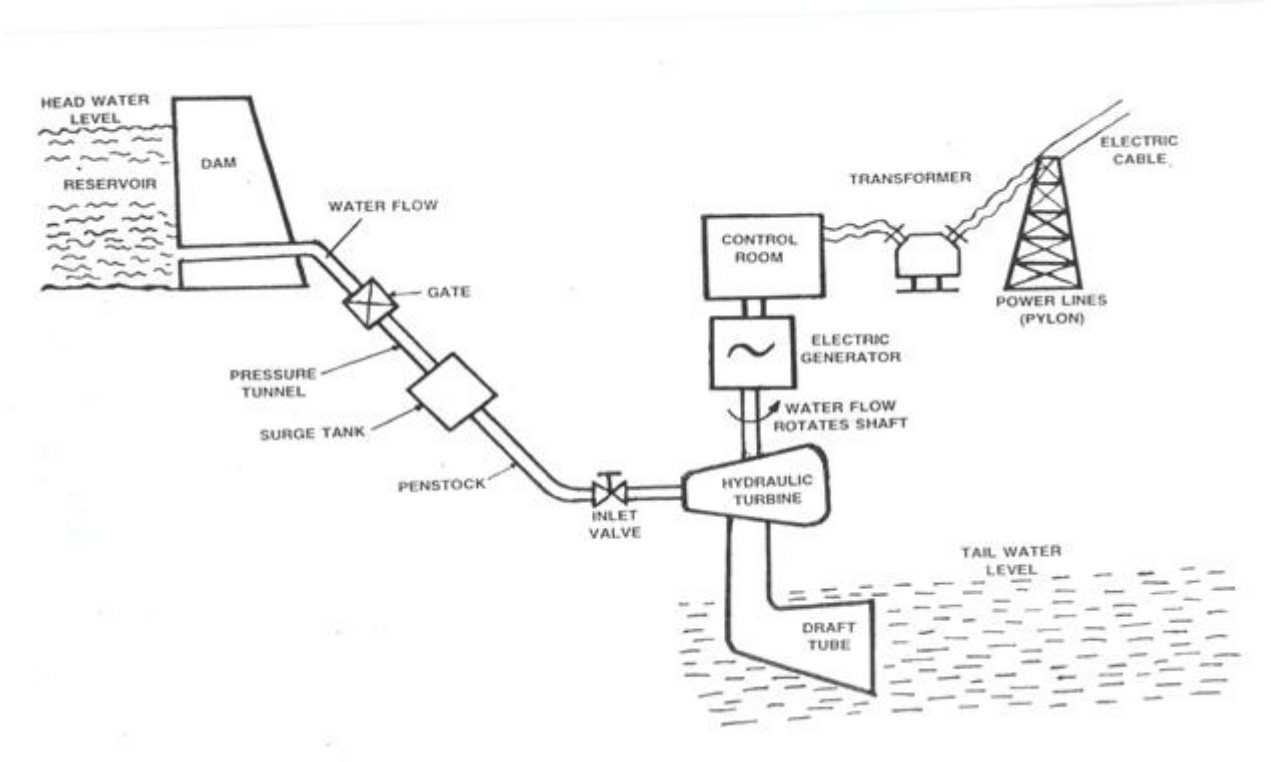


Fig 1.1 hydro power plant layout

The essential elements of hydro power plants are

1. Catchment area.
2. Water reservoir
3. Dam
4. Trash rack
5. Fore bay
6. Surge tank
7. Penstock
8. Spillway
9. Water turbine or Prime movers
10. Draft tube
11. Power house

1. Catchment area:-

❖ The catchment area is the whole area behind the dam for collecting the rain water and drains the water in to river or steam.

❖ The portion of the rainfall that flows through the catchment area on the surface of the catch is known as runoff.

2. Water reservoir:-

❖ The main purpose of water reservoir is to store the water collected from catchment area during rainy season and supply the same during day season.

❖ A reservoir may be natural like a lake on a mountain or artificially built by constructing a dam across a river.

3. Dam:-

❖ A dam is an impenetrable structure constructed across the river with power plant on downstream sideand water storage on upstream side. They has mainly two functions such as

1. It develops an artificial reservoir with desired capacity to store the water up to the required level.
2. It creates the working head of water and increases the samr for the power generation.

4.Trash rack:-

❖ Trash racks are gate-like devices which are fitted to prevent the entry of the debris from the dam or from the forebay into the penstock.

❖ Otherwise debris may cause damages to wicket gate and turbine runners, or choke up the nozzle of the impulse turbines.

❖ It is made up of steel bars and requires special provisions against ice formation under severe winter conditions.

❖ Debris are removed either manually for less floating materials or mechanically for greater amount of floating material.

5.Forebay:-

❖ Forebay is a flow variation absorber which serves as a regulating storage reservoir for temporarily storing water when the load on the plant is reduced and provides water when the load is increased.

❖ Fore bays are suitable for low and medium head plants where the length of penstock is short.

6.Surge Tank:

❖ Surge tank is a temporary storage safety reservoir fitted to the penstock at a point near to the turbine.

❖ When the load on the generator is dropped, there is a sudden rise in pressure due to sudden backflow of water.

❖ Conversely, when the load on the generator is increased, vaccum builds up in the penstock.This phenomenon results in a hammering action called water hammer.

❖ It would damage the penstock. Thus, the surge tank is introduced between the dam and the power house to keep the back pressure to aminimum by avoiding sudden pressure rise in the penstock.

❖ There are three types of surge tanks are commonly used. They are

(i)Conical type.

(ii)Internal bell-mouth type.

(iii)Differential surge tank.

7. Penstock:-

❖ A Pressure conduit, pipeline or tunnel located between the surge tank and prime mover to carry water under pressure is known as penstock.

❖ These are usually made of steel, reinforced concrete and even wood under certain conditions;

❖ Penstock may be either buried type or exposed type. In exposed type, penstock is not covered from exposed atmosphere and easily accessible for repair and maintenance works.

❖ In cold conditions, penstock is buried to prevent the ice formation in the pipe.

8. Spillway:-

❖ Spillway is considered as a safety valve for a dam.

❖ It must have the capacity to discharge major floods without damage to the dam and at the same time keeps the water level in the reservoir below the predetermined maximum level.

- Various types of spillways are
  - Overflow or solid gravity spillway
  - Chute or trough spillway
  - Side channel spillway
  - Saddle spillway
  - Shaft or glory hole spillway
  - Siphon spillway

9. Water turbine:-

- Hydraulic or water turbine is used to convert the hydraulic energy in to mechanical energy to produce electricity.
- The commonly used hydraulic turbine arepelton wheel turbine, Francis turbine, Kaplan turbine and propeller turbine.

10. Draft tube:-

- It is used only when the reaction turbine is used in the power plant. Due to its shape, the water flowing through the tube is decelerated.
- It comes out with the minimum kinetic energy and thus utilizing most of kinetic energy there by increasing the work output.
- It can be a straight conical type or an elbow tube. Conical tubes are used for low power units and hence elbow types are most common.

11. Power house:-

- A power house consists of two main parts
  1. Sub structure to support the hydraulic turbine and electrical equipment.
  2. Super structure to have and protect their equipments.

Advantages:

1. Water is the renewable source of energy. It is neither consumed nor converted into something else
2. Variable load does not affect the efficiency in the case of a hydro plant
3. Maintenance cost is low
4. It requires less supervising staff for the operation of the plant

Disadvantages:

1. Hydro power projects are capital intensive with low of rate of return
2. Initial cost of the plant is high
3. It takes considerably longer time for its installation compared with thermal power plants

2. i) How the hydro power is classified? (ii) What are the differences between high head power plant and pumped storage power plants? Explain with a neat sketch. [Nov/Dec-2012,13][May/June 2012,2013]or Classification of hydel power plants depends on following factors or classify the hydro electric plants according to availability of heat and nature of load.(may/june 15)

1. Quantity of water
   a. Run of river plant
   b. storage plant
   c. pumped storage plant
2. Availability of head of water
   a. Low head plant
   b. Medium head plant
   c. High head power plant

3. Classification according to topography
   a. Low land
   b. Hilly area
   c. Mountain region
4. Classification according to load supplied
   a. Base load plant
   b. Peak load plant
5. Classification according to capacity of plant.
   a. Micro hydel – upto 5 MW
   b. Medium capacity plants – 5 to 100 MW
   c. High capacity plants – 100 to 1000 MW
   d. Super plants – above 1000 MW
6. Classification according to turbine characteristic I.e. specific speed
   a. High specific speed
   b. Low specific speed

High head power plant:

❖ When the head of water exceeds 50 m the plant is known as head power plant. A surge tank is attached to the penstock to reduce the water hammer effect on the penstock.

❖ Pelton turbines are used in such power plants.

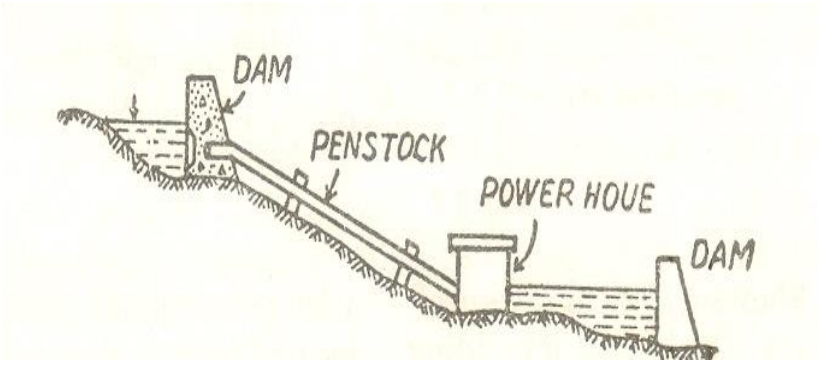


Fig 2.1 High head power plant

Low Head Plant:

❖ A low-head hydro project generally describes an installation with a fall of water less than 5 metres (16 ft).

❖ Most current hydroelectric projects require a large hydraulic head to power turbines to generate electricity.

❖ The hydraulic head either occurs naturally, such as a waterfall, or is created by constructing a dam in a river bed, creating a reservoir.

❖ Using a controlled release of water from the reservoir creates the head required to turn the turbines.

❖ The costs and environmental impacts of constructing a dam make traditional hydroelectric projects difficult to construct.

low-head hydro may dramatically reduce the following:

- The safety risks (of having a dam), avoiding the risk of a flash flood caused by a breached dam
- Environmental and ecological complications
  - Need for fish ladders
  - Silt accumulation in basin
- Regulatory issues

- The initial cost of dam engineering and construction
- Maintenance
    - Removing silt accumulation.

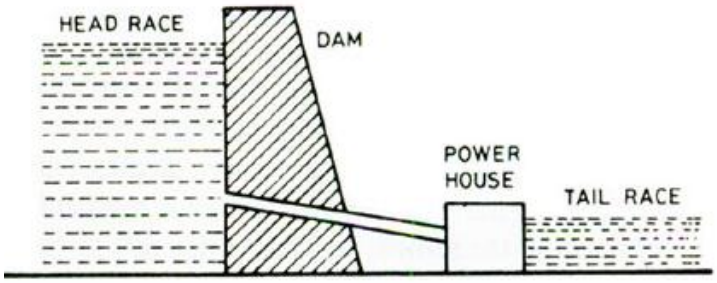


Fig 2.2 low head plant

3.Discuss the pumped storage hydel plant with neat sketches and high light their advantage.(may/june 15,nov/dec 14) or Describe pumped storage powerplant with neat diagram.(may/june 14) orWhat is pumped storage plant?Explain with neat sketch?(may/june 16)

Pumped storage plant

❖ Pumped storage plant in combination with hydro electric power plant is used for supplying the sudden peak load of short duration the water leaving the turbine of hydro electric power plant is store in tail race pond.

❖ This water is pumped back to the head race reservoir by means of reversible pump turbine set and is used for power generation at the peak load time.

❖ Pump storage are generally interconnected with other plants such steam power plants.

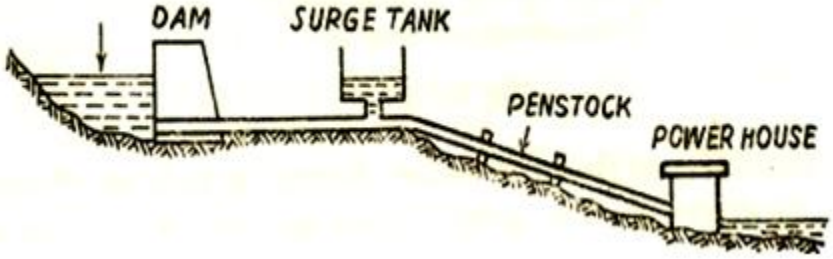


Fig 2.3 Pumped storage plant

Principle

❖ The basic principle of pumped storage is to convert the surplus electrical energy available in a system in off-peak periods, to hydraulic potential energy, in order to generate power in periods when the peak demand on the system exceeds the total available capacity of the generating stations.

❖ By using the surplus scheme electrical energy available in the network during low-demand periods, water is pumped from a lower pond to an upper pond.

❖ In periods of peak demand, the power station is operated in the generating mode i.e. water from the upper pond is drawn through the same water conduit system to the turbine for generating power.

There are two main types of pumped storage plants:

i) Pumped-storage plants and

ii) Mixed pumped-storage plants.

Pump-storage plants:

- In this type only pumped storage operation is envisaged without any scope for conventional generation of power.
- These are provided in places where the run-off is poor. Further, they are designed only for operation on a day-to-day basis without room for flexibility in operation.

Mixed pumped-storage plants:

- In this type, in addition to the pumped storage operation, some amount of extra energy can be generated by utilizing the additional natural run-off during a year.
- These can be designed for operation on a weekly cycle or other form of a longer period by providing for additional storage and afford some amount of flexibility in operation.

Pumped Storage Plant

- Water is utilized for generation of power during peak demand, while same water is pumped back in the reservoir during off peak demand period, when excess power is available for this purpose.
- If turbine is reversible, it can be used as a pump to supply water back to reservoir,

Otherwise separate pump can be used.

Based on operating cycle it can be classified as:

(a) **Plant with a daily cycle:** water is pumped up from mid night to early morning as well asnear lunch time.

(b) **Plant with a weekly cycle:** water is pumped up during weekend.

(c) **Plant with a seasonal cycle:** water is pumped up in the winter continuously for several days to be utilized for a continuous power generation in the high demand summer period

Four pumped storage hydro power plants in India

1. Bihar, Maharastra, 150 MW
2. Kadamparai, Coimbatore, Tamilnadu, 400MW
3. NagarjunaSagar PH, Andhra Pradesh,810MW
4. Purulia pumped storage project, Avodhvahills,West Bengal, 900MW

The advantages of pumped storage power plants:

1. Increases the peak load capacity at low cost
2. High operating efficiency
3. Better load factor
4. Independence of steam flow conditions

4. What is the basis for selecting a site for hydro power plants? Explain. (Dec 2012) or Write on the factor that should be considerd while selecting a site for a hydroelectric plant?(may/june 16)(Nov/Dec 2016)

- While selecting a suitable site for a hydro-electric power plant, if a good system of natural storage-lakes at high altitudes and with large catchment areas can be located, the plant will be comparatively economical.

The factors to be considered for site selection Hydro power plants are

- distance from load centre
- availability of land at reasonable rate
- availability of fuel at reasonable rate
- availability of transportation facilities
- distance from populated area and type of land
- Anyhow the essential characteristics of a good site are:

- ✓ large catchment area,
- ✓ high average rain fall and
- ✓ A favorable place for constructing the storage or reservoir.
- ✓ The land should be cheap in cost and rocky in order to withstand the weight of large building and heavy machinery.
- ✓ There should be possibility of providing adequate transportation facilities so that the necessary equipment and machinery could be easily transported.

5. Describe the various types of hydraulic turbines in hydro plants.(Nov/Dec 2012) or Write about selection of water turbine?Explain any one turbine with neat sketch used in hydro electric power plant?(nov/dec 14)

Hydraulic Turbines

- ❖ Hydraulic Turbines transfer the energy from a flowing fluid to a rotating shaft. Turbine itself means a thing which rotates or spins. Hydraulic Turbines have a row of blades fitted to the rotating shaft or a rotating plate.
- ❖ Flowing liquid, mostly water, when pass through the Hydraulic Turbine it strikes the blades of the turbine and makes the shaft rotate.
- ❖ While flowing through the Hydraulic Turbine the velocity and pressure of the liquid reduce, these result in the development of torque and rotation of the turbine shaft.
- ❖ There are different forms of Hydraulic Turbines in use depending on the operational requirements. For every specific use a particular type of Hydraulic Turbine provides the optimum output.
- ❖ Hydraulic Turbines are being used from very ancient times to harness the energy stored in flowing streams, rivers and lakes. The oldest and the simplest form of a Hydraulic Turbine was the Waterwheel used for grinding grains. Different types of Hydraulic Turbines were developed with the increasing need for power. Three major types are Pelton Wheel, Francis and Kaplan Turbine.

Classification of Hydraulic Turbines: Based on flow path

Water can pass through the Hydraulic Turbines in different flow paths. Based on the flow path of the liquid Hydraulic Turbines can be categorized into three types.

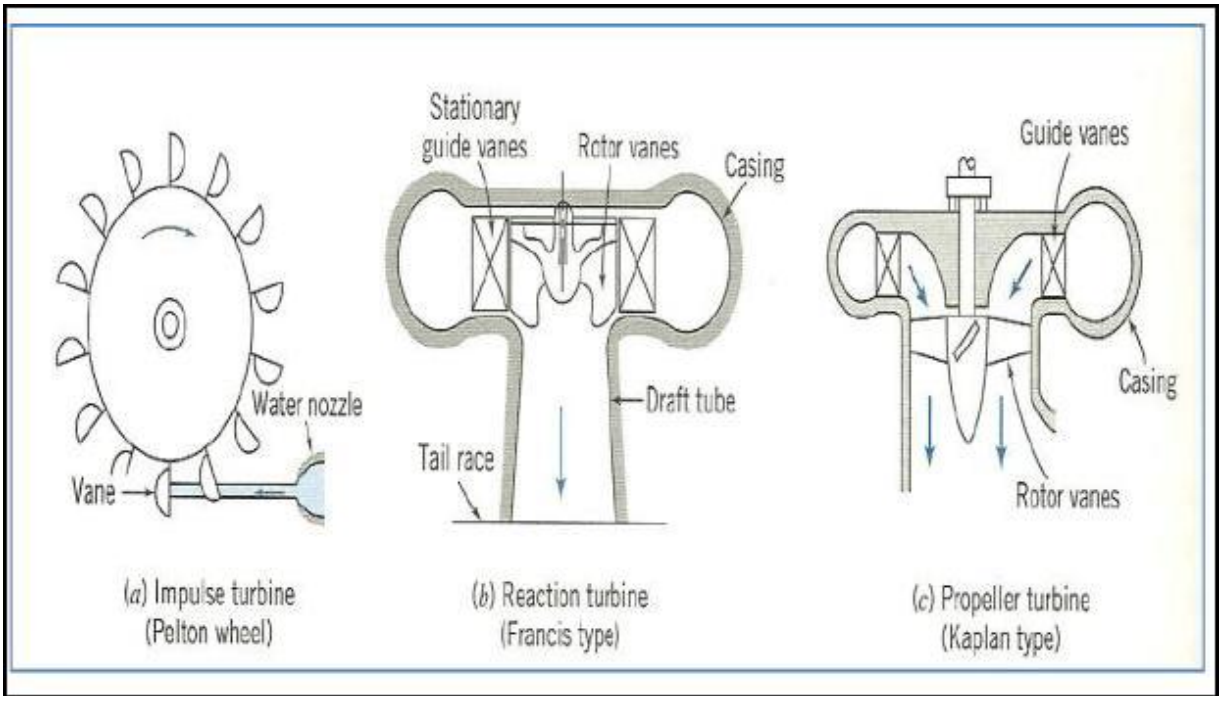
1. **Axial Flow Hydraulic Turbines:**
   - ❖ This category of Hydraulic Turbines has the flow path of the liquid mainly parallel to the axis of rotation. Kaplan Turbines has liquid flow mainly in axial direction.
2. **Radial Flow Hydraulic Turbines:**
   - ❖ Such Hydraulic Turbines has the liquid flowing mainly in a plane perpendicular to the axis of rotation.
3. **Mixed Flow Hydraulic Turbines:**
   - ❖ For most of the Hydraulic Turbines used there is a significant component of both axial and radial flows.
   - ❖ Such types of Hydraulic Turbines are called as Mixed Flow Turbines. Francis Turbine is an example of mixed flow type, in Francis Turbine water enters in radial direction and exits in axial direction.

❖ None of the Hydraulic Turbines are purely axial flow or purely radial flow. There is always a component of radial flow in axial flow turbines and of axial flow in radial flow turbines.

Classification of Hydraulic Turbines: Based on pressure change

❖ One more important criterion for classification of Hydraulic Turbines is whether the pressure of liquid changes or not while it flows through the rotor of the Hydraulic Turbines.

❖ Based on the pressure change Hydraulic Turbines can be classified as of two types.



4. **Impulse Turbine:**
   - ❖ The pressure of liquid does not change while flowing through the rotor of the machine.
   - ❖ In Impulse Turbines pressure change occur only in the nozzles of the machine. One such example of impulse turbine is Pelton Wheel.
5. **Reaction Turbine:**
   - ❖ The pressure of liquid changes while it flows through the rotor of the machine.
   - ❖ The change in fluid velocity and reduction in its pressure causes a reaction on the turbine blades; this is where from the name Reaction Turbine may have been derived. Francis and Kaplan Turbines fall in the category of Reaction Turbines.

6.Explain the working of Francis turbine with Pelton wheel and give its merits and demerits (Nov/Dec 2013)

FRANCIS TURBINE:

- ❖ In Francis Turbine water flow is radial into the turbine and exits the Turbine axially. Water pressure decreases as it passes through the turbine imparting reaction on the turbine blades making the turbine rotate.
- ❖ Francis Turbine is the first hydraulic turbine with radial inflow. It was designed by American scientist James Francis.
- ❖ Francis Turbine is a reaction turbine. Reaction Turbines have some primary features which differentiate them from Impulse Turbines.
- ❖ The major part of pressure drop occurs in the turbine itself, unlike the impulse turbine where complete pressure drop takes place up to the entry point and the turbine passage is completely filled by the water flow during the operation.
- ❖ Francis Turbine has a circular plate fixed to the rotating shaft perpendicular to its surface and passing through its centre.
- ❖ This circular plate has curved channels on it; the plate with channels is collectively called as runner.
- ❖ The runner is encircled by a ring of stationary channels called as guide vanes.
- ❖ Guide vanes are housed in a spiral casing called as volute. The exit of the Francis turbine is at the centre of the runner plate. There is a draft tube attached to the central exit of the runner.

Working of Francis Turbine:

- Francis Turbines are generally installed with their axis vertical. Water with high head (pressure) enters the turbine through the spiral casing surrounding the guide vanes.
- The water looses a part of its pressure in the volute (spiral casing) to maintain its speed.
- Then water passes through guide vanes where it is directed to strike the blades on the runner at optimum angles.
- As the water flows through the runner its pressure and angular momentum reduces. This reduction imparts reaction on the runner and power is transferred to the turbine shaft.
- If the turbine is operating at the design conditions the water leaves the runner in axial direction.
- Water exits the turbine through the draft tube, which acts as a diffuser and reduces the exit velocity of the flow to recover maximum energy from the flowing water

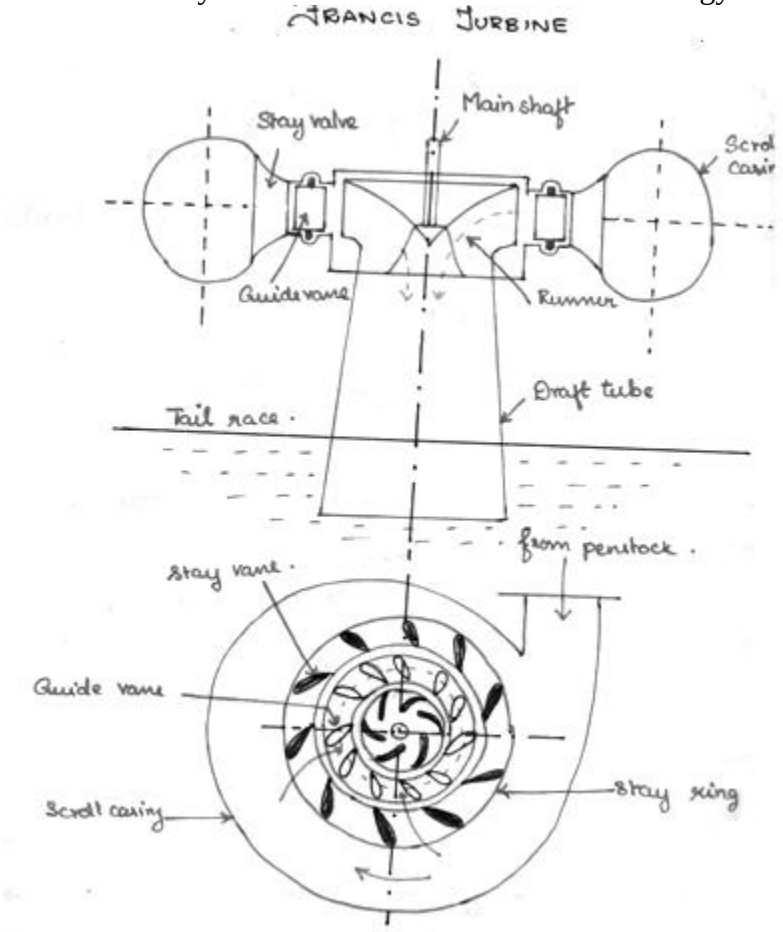


Fig 7.1 Francis Turbine

Power Generation using Francis Turbine

- For power generation using Francis Turbine the turbine is supplied with high pressure water which enters the turbine with radial inflow and leaves the turbine axially through the draft tube.
- The energy from water flow is transferred to the shaft of the turbine in form of torque and rotation.
- The turbine shaft is coupled with dynamos or alternators for power generation. For quality power generation speed of turbine should be maintained constant despite the changing loads.

Advantages of Francis Turbine:

- The variation in the operating head can be more easily controlled in Francis turbine than in Pelton wheel turbine
- The ratio of maximum and minimum operating head can be even be two in the case of Francis Turbine
- The operating head can be utilized even when the variation in the tail water level is relatively large when compared to the total load
- The size of the runner, generator and power house required is small and economical if the Francis turbine is used instead of Pelton wheel for the same power generation.
- The mechanical efficiency of the pelton wheel decreases faster with wear than Francis turbine

Drawbacks of Francis Turbine:

- Water which is not clean can cause very rapid wear in high head Francis turbine. In passing through the guide vanes and cover facings, it can quickly reduce overall efficiency of the turbine by several percentage. The effect is much more serious in turbines of smaller diameter than in larger ones
- Particles of solid matter in the water will wear the tip of the spear, the nozzle and after several years the runners also. The first two components are easily removable, renewable and repairable. The runner repairing by welding can often be done without removing the runner from the shaft or casing
- The inspection and overhaul of a Francis Turbine is much more difficult job than that of the equivalent pelton turbine.
- Cavitation is an ever present danger in Francis Turbine as well as in all the reaction turbines. The raising of the power house floor level to reduce the danger of flooding may be followed by the endless cavitation troubles
- Usually below 60% load, the pelton wheels have much better efficiency than the Francis turbine of lower specific speeds. If there is a possibility of running the prime mover below 50% load for long time, the Francis will not lose efficiency but cavitation danger will become more serious
- The water hammer effect with the Francis turbine is more troublesome than the pelton turbine

7. Explain the working of Pelton wheel turbine and give its merits and demerits (Nov/Dec 2013)

PELTON TURBINE:

- In a Pelton Turbine or Pelton Wheel water jets impact on the blades of the turbine making the wheel rotate, producing torque and power.
- The Pelton Turbine has a circular disk mounted on the rotating shaft or rotor.
- This circular disk has cup shaped blades, called as buckets, placed at equal spacing around its circumference.
- Nozzles are arranged around the wheel such that the water jet emerging from a nozzle is tangential to the circumference of the wheel of Pelton Turbine.
- According to the available water head (pressure of water) and the operating requirements the shape and number of nozzles placed around the Pelton Wheel can vary.

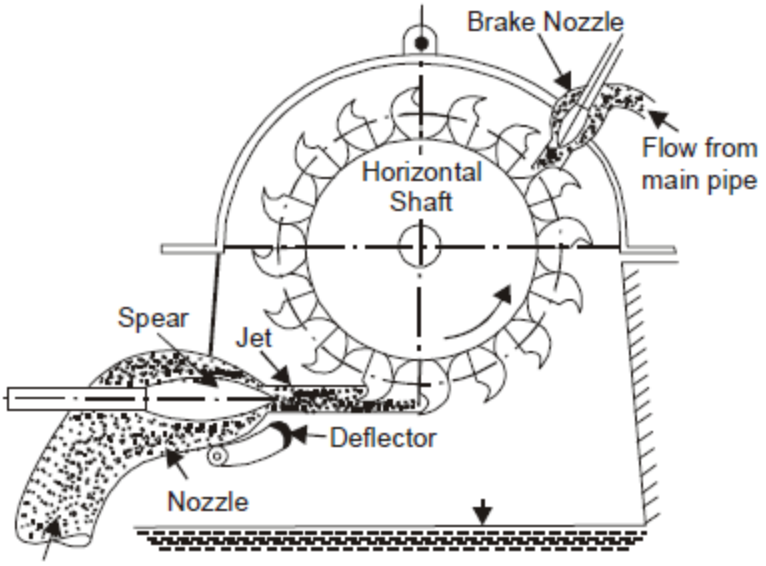


Fig 8.1 Pelton Turbine

Working Principle of Pelton Turbine

- The high speed water jets emerging form the nozzles strike the buckets at splitters, placed at the middle of a bucket, from where jets are divided into two equal streams. These stream flow along the inner curve of the bucket and leave it in the direction opposite to that of incoming jet.
- The high speed water jets running the Pelton Wheel Turbine are obtained by expanding the high pressure water through nozzles to the atmospheric pressure. The high pressure water can be obtained from any water body situated at some height or streams of water flowing down the hills.
- The change in momentum (direction as well as speed) of water stream produces an impulse on the blades of the wheel of Pelton Turbine. This impulse generates the torque and rotation in the shaft of Pelton Turbine.
- To obtain the optimum output from the Pelton Turbine the impulse received by the blades should be maximum. For that, change in momentum of the water stream should be maximum possible. That is obtained when the water stream is deflected in the direction opposite to which it strikes the buckets and with the same speed relative to the buckets.

Power Generation Using Pelton Turbine

- A typical setup of a system generating electricity by using Pelton Turbine will have a water reservoir situated at a height from the Pelton Wheel.
- The water from the reservoir flows through a pressure channel to the penstock head and then through the penstock or the supply pipeline to the nozzles, from where the water comes out as high speed jets striking the blades of the Pelton Turbine.
- The penstock head is fitted with a surge tank which absorbs and dissipates sudden fluctuations in pressure.
- For a constant water flow rate from the nozzles the speed of turbine changes with changing loads on it. For quality hydroelectricity generation the turbine should rotate at a constant speed.
- To keep the speed constant despite the changing loads on the turbine water flow rate through the nozzles is changed. To control the gradual changes in load servo controlled spear valves are used in the jets to change the flow rate.
- And for sudden reduction in load the jets are deflected using deflector plates so that some of the water from the jets do not strike the blades. This prevents over speeding of the turbine.

There are many advantages of using this turbine over other which are following

- Pelton wheel turbine is an impulse turbine

- It operates on high head and low discharge.
- It has tangential flow which means that it can have either axial flow or radial flow.
- Pelton wheel turbine is very easy to assemble.
- There is no cavitation because water jet strikes only a specific portion of the runner.
- It has fewer parts as compared to francis turbine which has both fixed vanes and guided vanes.
- Its overall efficiency is high.
- On pelton wheel turbine, both first law and second law of motion is applied.
- In this turbine, whole process of water jet striking and leaving to the runner takes place at atmospheric pressure.

8. Explain the working of Kaplan turbine and give its merits and demerits (or) Compare and contrast Kaplan turbine with Francis turbine. (May/June 2012) or State the advantages of inward floe reaction turbine over outward flow reaction turbine? (APR/MAY 2018)

KAPLAN TURBINE:

- Kaplan Turbine is designed for low water head applications. Kaplan Turbine has propeller like blades but works just reverse.
- Instead of displacing the water axially using shaft power and creating axial thrust, the axial force of water acts on the blades of Kaplan Turbine and generating shaft power.
- Most of the turbines developed earlier were suitable for large heads of water.
- With increasing demand of power need was felt to harness power from sources of low head water, such as, rivers flowing at low heights.
- For such low head applications Viktor Kaplan designed a turbine similar to the propellers of ships. Its working is just reverse to that of propellers. The Kaplan Turbine is also called as Propeller Turbine.
- To generate substantial amount of power from small heads of water using Kaplan Turbine it is necessary to have large flow rates through the turbine.
- Kaplan Turbine is designed to accommodate the required large flow rates.
- Except the alignment of the blades the construction of the Kaplan Turbine is very much similar to that of the Francis Turbine.
- The overall path of flow of water through the Kaplan Turbine is from radial at the entrance to axial at the exit. Similar to the Francis Turbine, Kaplan Turbine also has a ring of fixed guide vanes at the inlet to the turbine.
- Unlike the Francis Turbine which has guide vanes at the periphery of the turbine rotor (called as runner in the case of Francis Turbine), there is a passage between the guide vanes and the rotor of the Kaplan Turbine.
- The shape of the passage is such that the flow which enters the passage in the radial direction is forced to flow in axial direction.

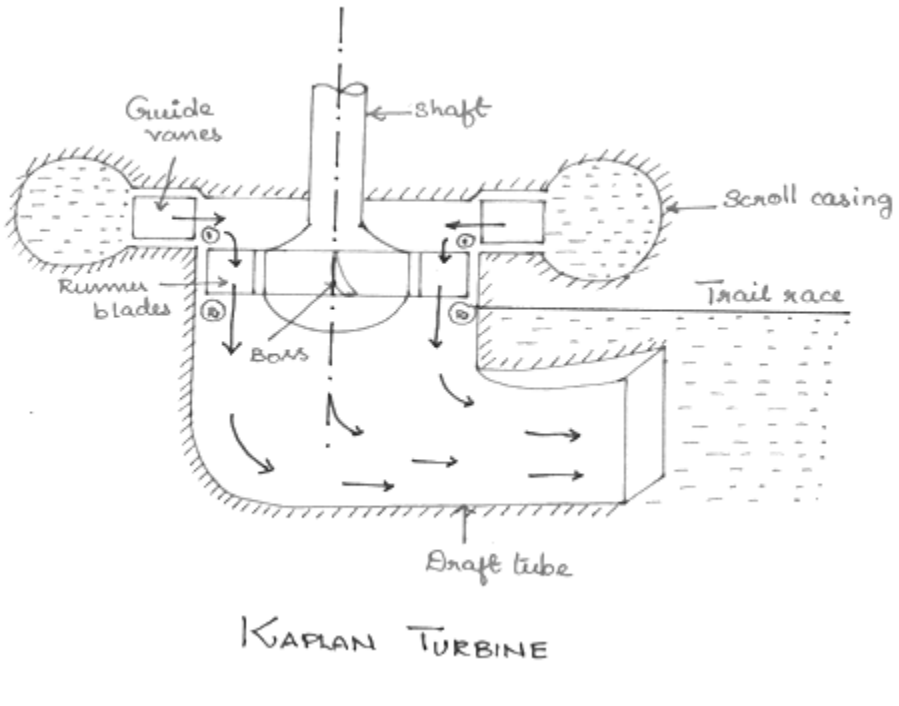


Fig 9.1 Kaplan Turbine

- The rotor of the Kaplan Turbine is similar to the propeller of a ship. The rotor blades are attached to the central shaft of the turbine.
- The blades are connected to the shaft with moveable joints such that the blades can be swivelled according to the flow rate and water head available.
- The blades of the Kaplan Turbine are not planer as any other axial flow turbine; instead they are designed with twist along the length so as to allow swirling flow at entry and axial flow at exit.

Working of the Kaplan Turbine

- The working head of water is low so large flow rates are allowed in the Kaplan Turbine.
- The water enters the turbine through the guide vanes which are aligned such as to give the flow a suitable degree of swirl determined according to the rotor of the turbine.
- The flow from guide vanes pass through the curved passage which forces the radial flow to axial direction with the initial swirl imparted by the inlet guide vanes which is now in the form of free vortex.
- The axial flow of water with a component of swirl applies force on the blades of the rotor and loses its momentum, both linear and angular, producing torque and rotation (their product is power) in the shaft.
- The scheme for production of hydroelectricity by Kaplan Turbine is same as that for Francis Turbine.

Advantages of Kaplan Turbine over Francis Turbine

- It is more compact in construction and smaller in size for the same power developed
- Its part load operating efficiency is considerably high. The efficiency curve of Kaplan turbine remains flat for over the whole load range .
- The frictional losses passing through the blades considerably lower due to small number of blades used in Kaplan Turbine.

9.With neat sketch explain the working of wind power plant. (Nov/Dec 2009, April/May 2010,11) (NOV/DEC 2017)

- Wind as a source of energy and is plentiful, inexhaustible and pollution free, but it has disadvantage of degree and period of its availability are uncertain. For moderate amount of power, large volumes of air are required.
- The power that can be theoretically obtained from wind is proportional to the cube of its velocity.
- Wind results from air in motion. Air in motion arises from the pressure gradient. The wind is basically caused by solar energy radiating the earth.
- The useful work done for the conversion of kinetic energy of the wind into mechanical energy can be utilized to generate the electricity.
- Most of the machines for converting wind energy into mechanical energy consist of number of sails, vanes, or blades radiating air from the hub or the central axis.
- When wind blows against the vanes or the blades, they rotate about the axis and the rotational motion can be used to perform the useful work.
- Wind energy conversion devices are known as wind turbines, because they convert wind stream into energy of rotation because the wind turbine produces rotational motion.
- Wind energy is readily converted into electrical energy by connecting the turbine to an electric generator.

Basic principle of wind energy conversion

- Wind possesses energy by virtue of its motion. Any energy conversion device can extract this and convert it into useful work depending on:

1. the wind speed,
2. the cross-section of wind swept by the rotor, and
3. The overall efficiency of the rotor and generator efficiency.

- The power in the extracted wind can be found out by kinetics concept. The amount of air passing in unit time through an area „A" with velocity „V" is $A \times V$.

And, mass is given by

$$M=PAV,$$

Where p is the density of the air,

Kinetic energy of the particle is given by ,$E= \frac{1}{2} MV^2$

$$E=\frac{1}{2}PAV^2$$

- Above gives maximum wind energy available and is proportional to the cube of the wind speed.
- The power developed using this law, the density of air is 1.2014 kg /cu m [atmosphere condition], is given by
- Power developed = 13.14 $\times 10\_6\ AV\ 3\ KW$ Where, A = swept area in square meter.

V = wind velocity in km / hr

The energy developed is affected by,

1. The altitude of the site.
2. Velocity duration curve. [Variation of velocity of wind over the period affects the power output].

Types of wind mills

- A wind mill is machine, which plays major role in wind energy conversion. Wind turbine that converts the kinetic energy of the wind motion to the mechanical energy transferred to an electric generator through the shaft.

- Electric generator converts mechanical energy into electrical energy.
- Normally, based upon the axis of rotation of turbine, wind mills are classified into two types.
- They are:

1. Horizontal axis wind mill.

2.Vertical axis wind mill

- In horizontal axis, wind mill uses motional wind energy for the rotation of shaft, in which the axis of rotation of the shaft is along horizontal axis and the aero turbine plane is vertically facing to the wind.
- In vertical axis wind mill type, the axis of rotation of the shaft is along the vertical axis and the aero turbine plane is horizontally facing the wind.
- The revolving shaft rotates the rotor of a generator through gear coupling mechanism

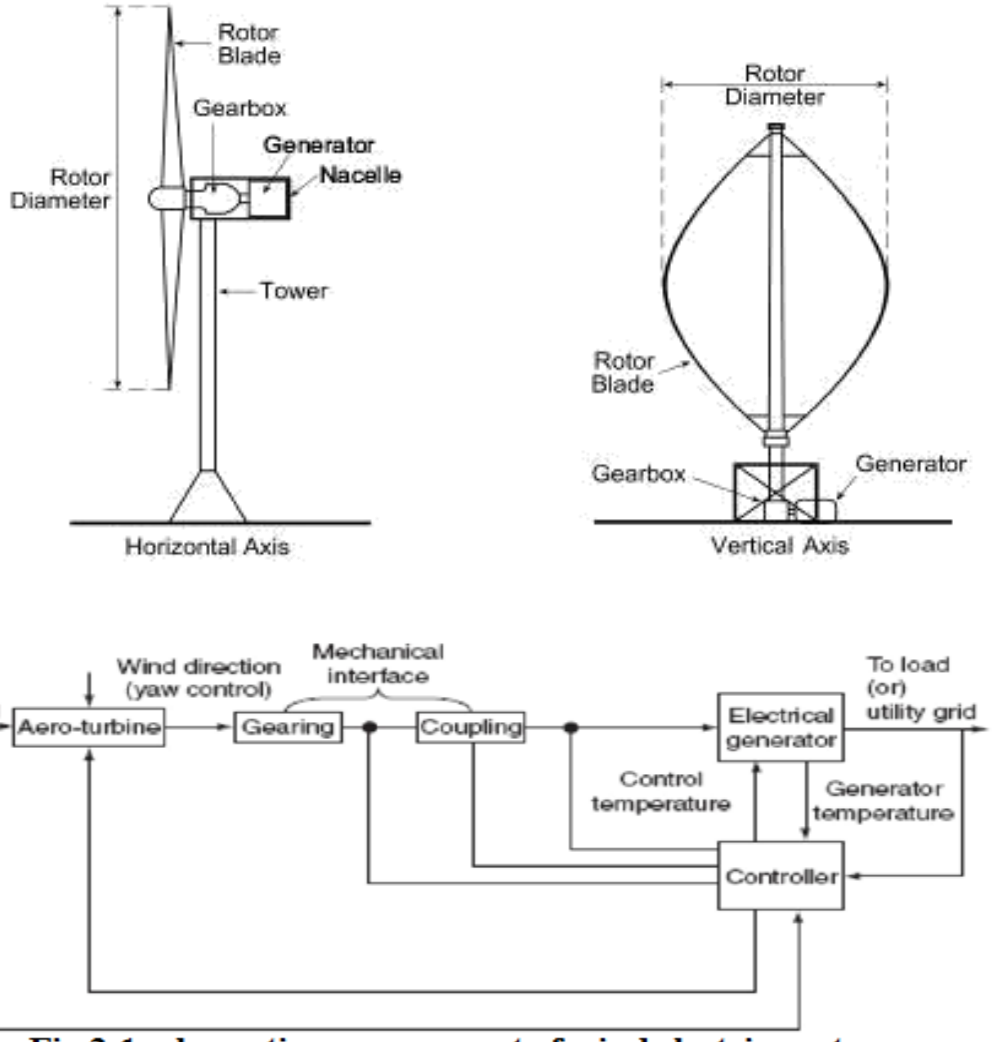


Fig 2.1 schematic arrangement of wind electric system

Basic components of wind energy conversion plant

- The block diagram representation of the wind energy conversion system is shown in Fig 2.1

The main components of the wind energy conversion system are:

1. **Aero turbine**:
   Aero turbines convert wind energy into rotary mechanicalenergy. This block requires pitch and yaw, i.e., direction of wind flow control for proper operation.
2. **Mechanical interface (coupling & gearing):**

A suitable mechanical gearshould be provided to transmit mechanical energy into electric generator.

3. **Electric generator:**
   Generator that converts mechanical energy from theaero turbine into electrical energy and is connected to the load and or power grid.
4. In wind energy-generation system, wind turbine converts kinetic energy of wind motion into mechanical energy with the help of blades. The direction of wind flow control, i.e., pitches and yaw control is required for the proper operation. A suitable mechanical transmission gear is provided to transmit the mechanical energy from the wind turbine to electrical generator.

- An electric generator converts mechanical energy into electrical energy and is fed to the rectifier thereby converting fixed AC to variable DC supply.
- Further DC is fed to an inverter, which converts DC into variable AC supply, transmitted to grid system for utility purpose.

Site selection for wind energy conversion plant

Various factors on site selection that are need to be considered while erecting a wind energy conversion plant is:

- Site for the wind plant should be nearer to the consumers of the generated electrical energy.
- It must be convenient for transportation facility.
- Plant should be erected in the place, where winds are strong and persistence.
- Plant must be installed at higher attitudes, where the motion of wind energy is available with higher velocity.
- The land cost should be low.
- It is better to choose the site nearer to the sea coast, mountains, etc. for the wind.
- Energy conversion plant

Advantages and disadvantages of wind power(Nov/Dec 2016)

Advantages

- Wind is renewable source of energy.
- There is no need of using fuel for wind energy conversion system.
- There is no need of transportation facility.
- It is pollution free.
- The maintenance cost of wind energy conversion system is less for low power generation.

Disadvantages

- The availability of wind energy is fluctuating in nature.
- The auxiliary storage devices such as battery must be provided for wind energy conversion system because of the fluctuation of the wind in nature.
- Wind energy conversion systems are noisy.
- More space should be needed for wind power generation.
- The structure of wind power conversion system is complex and the weight of system is also high due to the construction of high towers.

Applications of wind energy

- Wind machines can generate low power for space heating and cooling of homes.
- The electric energy generated from the wind stations can be adoptable for domestic appliances.
- Low power wind energy conversion systems have been used for corrosion protection of buried metal pipelines.

- Wind power turbines up to 50 kW can be used for irrigation pumps, navigational signals, remote communications, etc

10. Explain the main components and working of tidal power plant. (Nov/Dec -2012, May/June – 2013) or Describe the energy generation cycle of "Single basin single effect" and " Single basin double effect" Systems? (NOV/DEC 2017)

Non- conventional:

- The non-conventional sources of energy like wind, tidal, solar etc. were conventional sources before the invention of steam turbine [James Watt].
- The non-conventional sources are face of coot, air pollution face and inexhaustible.

Tidal Power:

- Tidal power is also said to be lunar energy. Tides are caused by the combined gravitational forces of sun and the moon on the water of revolving earth.
- When the forces of sun and moon add together, tides of maximum range said to be spring tides.
- When the two forces oppose each other, tides of minimum range said to be neap tides. In one year, 705 full tidal cycles are seen.
- For harnessing the tidal power effectively, the most practicable method is the Basin system. Here a portion of the sea is enclosed behind a dam and water is allowed to sun through turbines, as the tides subside.
- The power varies with the variation in availability of tidal power.

Components of tidal power plant

The tidal power plant has the following main parts:

1. **Dam or dyke**: A dam or dyke is nothing but a barrier that exists between sealevel and a basin or between a basin and the other in case of a multiple basin.
2. **Power house**: The tidal power plant equipment such as turbine, electricgenerator, and other auxiliary devices are placed in the power house.
3. **Sluice-ways**: It is nothing but a gate-controlled way either to fill the basinduring high-tide period or it will keep empty during low tide.

Single Basin System:

- It is the simplest scheme, a single brain of constant area is provided with sluices [gate], large enough to admit the tide.
- The level of water in the brain is same as that of the tide outside. When the tides are high, water is stored in the basin and sluices are closed.
- When the tides are falling, sluices are opened to allow water to go through the turbine to generate power.

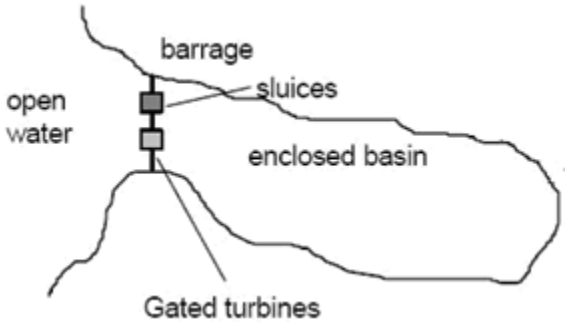


Fig 1.1 Single basin system

- The major disadvantage of this system is that it gives intermittent supply of power, varying over the period of operation; only 50% of tidal energy is available.

Double Basin Systems:

- An improvement of single basin system is the two basin system. In this, a constant and continuous output is maintained by adjusting turbine values.
- A two basin systems regulates output power of individual tidal, but cannot show the output difference between spring and neap tides. This disadvantage can be overcome by joining the operation of tidal power and pumped storage plant.
- During period, when the tidal power plant is producing more energy than required, the pumped storage plant utilizes the surplus power for pumping the water to the upper reservoir.
- When the output of tidal power plant is low, the pumped storage plant generates electric power and feeds it to the system.
- Even though it is technically feasible, is much more expensive one also. The joint operation of tidal power with steam plant also possible, if it connected to grid.
- The double basin system shown above in which two basins are close to each other, operates alternatively.
- One basin generates power when tide is rising (basin getting filled up) and other basin generates when tide is falling (basin getting emptied).
- The two basins have common or separate power house. So the power can be generate continuously.
- It consists of 2 basins with different elevation connected through turbine. The high level basin sluices are called the inlet sluices and the low level as outlet sluices.

- Assuming that the upper basin is filled with water. The water is allowed to flow to the lower basin through turbine.

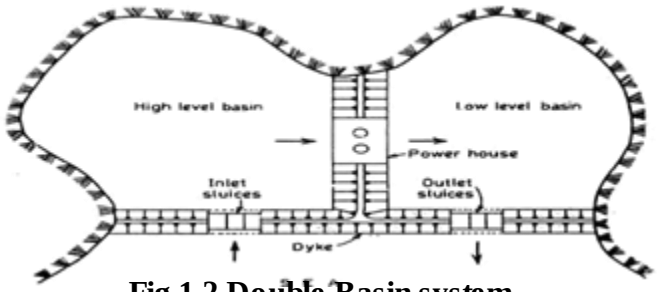


Fig 1.2 Double Basin system

- When the rising level in the basin is equal to the falling tide level, outlet sluices are opened.
- When the tide reaches its lower most level, the output sluices closed. After a while the tide rises, its level equal to low level of upper basin inlet sluice opens. Thus the cycle is repeated.

Turbine:

The turbines like Kaplan type, propeller type [angle of the blades can be alter to obtain maximum efficiency], horizontal turbine [equal efficiency as pump &as turbine].

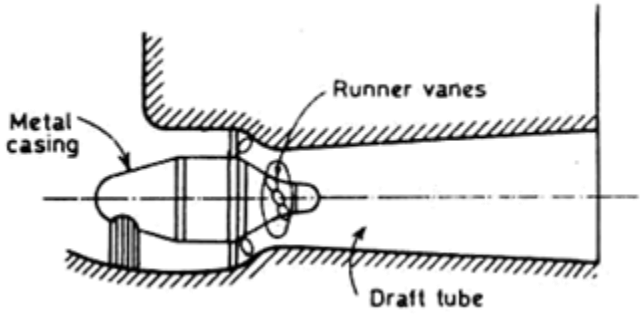


Fig 1.3 Bulb – type turbine

- ❖ The bulb type turbine consists of steel shell completely enclosing the generator coupled with turbine runner, fully submerged at all times.
- ❖ When the power demand on the system is low during the rising tides, the unit operates as a pump [sea to basin]. When load is high, the unit will work as a generator and deliver the stored energy.

The Components of Tidal Power Station

- ❖ Barrage Turbines
- ❖ Sluices
- ❖ Embankments

Advantages of Tidal Power Generation.

1.Renewable and sustainable energy
2.No liquid or solid pollution
3.Little visual impact
4.Reduces dependence upon fossil fuel

Limitations of Tidal Energy.

1.Orientation problem
2.Requires storage devices
3.Available at a lower rating and time
4.High capital cost

Site selection of tidal power plant

Various factors that are needed to be considered for the location of tidal power plant are:

- ❖ The location of the plant must be nearer to the ocean.
- ❖ Site selection for the plant should be in such a way that the tidal range of ocean is large.
- ❖ The geographic features of the plant must be encloses of large areas with short dams
- ❖ The sluice gates of dam should allow water to or from the basins.

10.Explain in detail about the working of geothermal power plant. Or Explain about Hot Springs and Steam Ejection (May/June – 2012) (Nov/Dec 2013)

- ❖ The earth‟s interior is made of a hot fluid called „magma‟. The outer crust of earth is 32 km (thickness).
- ❖ The average increase in temperature with depth of the earth is $1^{\circ}C$ for every 35 to 40 meter depth. At a depth of 3 to 4 km, water boils and of about 15 km, the temperature range of $1000^{\circ}C\ to 1200^{\circ}C$ are seen.
- ❖ Magma finds the weak spot of the earth‟s crust results in volcano.

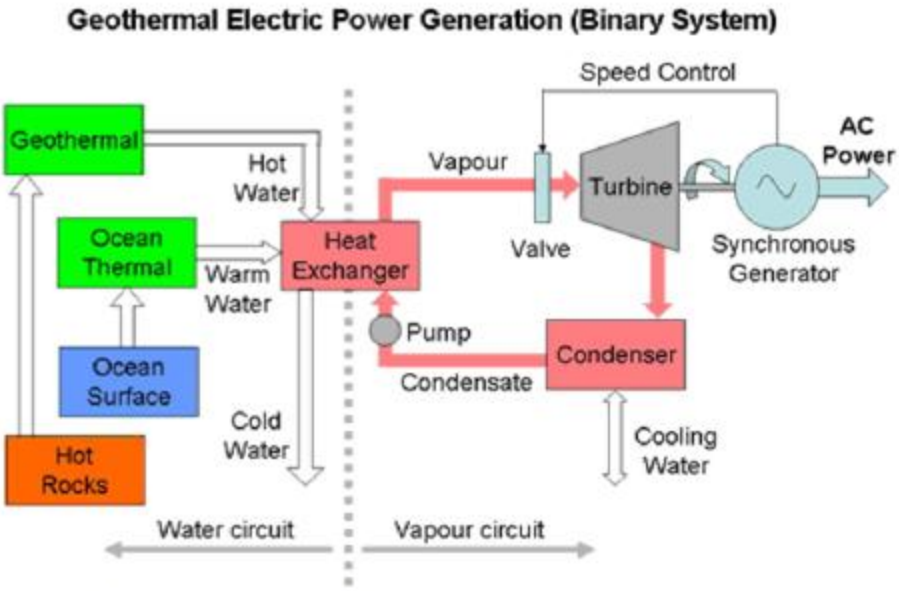


Fig 4.1 Binary fluid geothermal power system

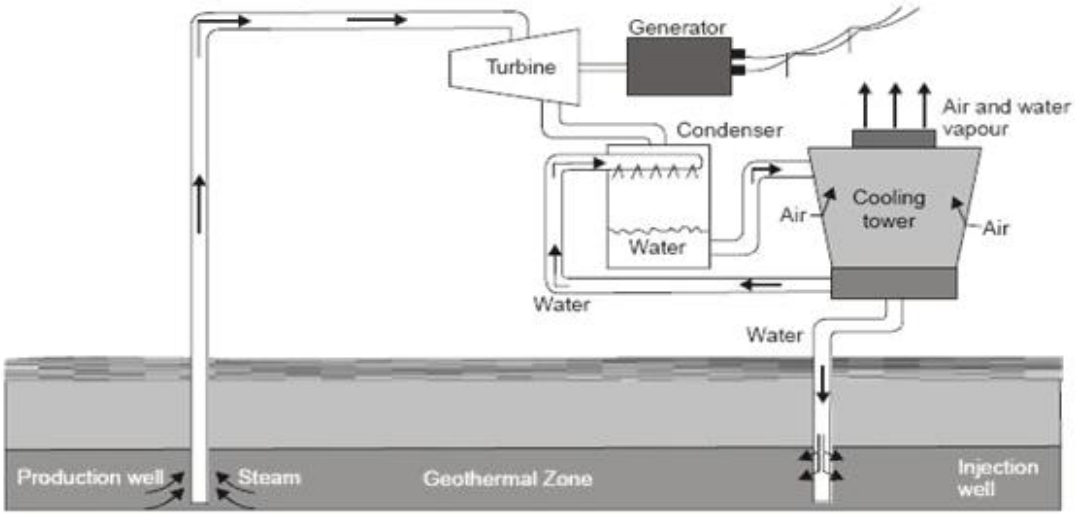


Fig 4.2.Dry steam power plant

Two types of cycles for geothermal power generation.

i. Indirect condensing cycle
ii. Direct non-condensing cycle

i. Indirect condensing cycle

- An indirect system was adopted to avoid corrode in the turbine. In this, heat exchanger is used, so clean steam was raised from contaminated natural steam. About 15% to 20% will be lossed due to heat exchanger.

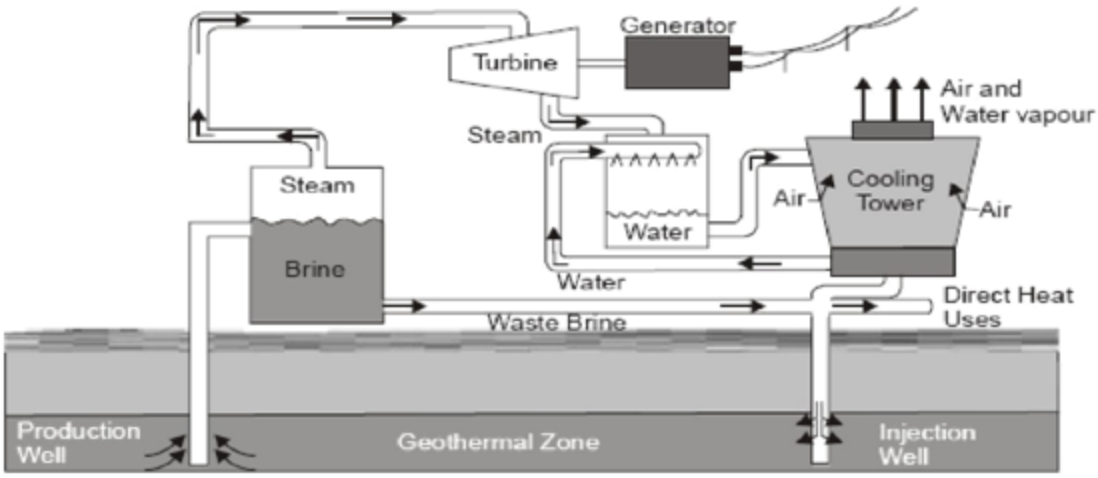


Fig 4.3 Flash steam power

ii. Direct non-condensing cycle:

- This is the simplest, cheapest and most widely used geothermal cycle.
- Bore steam directly from dry bores or after separation [using centrifugal separator] from wet bore, simply passes through a turbine and exhaust to atmosphere.

The Main Parts of Geothermal Power Plant

1. Production well
2. Vaporizer
3. Circulating pump
4. Expansion turbine
5. Generator
6. Condenser
7. Transformer

Advantages of Geothermal Energy

1. Cheaper
2. Versatile in its use
3. Delivers greater amount of energy

Disadvantages of Geothermal Energy

1. Drilling operation is noisy
2. It needs large areas of exploitation of geothermal energy
3. Low overall power production efficiency

Applications of Geothermal Energy

1. Generation of electric power
2. Space heating for building
3. Industrial process heat

11. Explain how the energy is cultivated using solar power and explain its collector system. (Or) Draw the Block diagram of a standalone solar PV power generation system. Also explain the role of individual blocks. (Nov/Dec 2013) or Briefly explain solar PV system.(Nov/dec 15) or Describe the function of a solar PV electric plant.(may/june 16)(May/ June 17) (NOV/DEC 2017)

❖ Sun is the primary source of energy. The earth receives 1.6×10^{18} units of energy from the sun annually.

Three broad categories of possible large scale applications are:

i. Heating and cooling of residential and commercial buildings.
ii. Chemical and biological conversion of organic material.
iii. Conversion of solar energy to electricity.

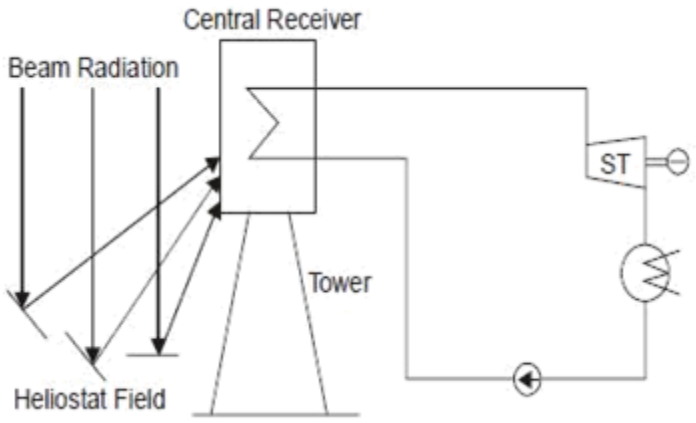


Fig. 5.1 Central Receiver Solar Power Plant.

❖ **'Solar Power Plant** The first is the 'Solar Power Tower' design which usesthousands of sun-tracking reflectors or heliostats to direct and concentrate solar radiation onto a boiler located atop a tower.

❖ The temperature in the boiler rises to 500 – 7000°C and the steam raised can be used to drive a turbine, which in turn drives an electricity producing turbine. There are also called central Receiver Solar Power Plants.

❖ It can be divided into solar plant and conventional steam power plant. The flow diagram is given in Fig.5.1

❖ A heliostat field consists of a large number of flat mirrors of 25 to 150 m2 areas which reflects the beam radiations onto a central receiver mounted on a tower. Each mirror is tracked on two axes. The absorber surface temperature may be 400 to 1000°C.

❖ The concentration ratio (total mirror area divided by receiver area) may be 1500. Steam, air or liquid metal may be used as working fluid. Steam is raised for the conventional steam power plant.

Residential cooling and heating:

❖ A flat plate collector is located on the roof of a house, which collects the solar energy.

❖ The cooling water is pumped through the tubes of the solar collector.

❖ The heat is transferred from the collector to the water and the hot water is stored in a storage tank, located at ground level or in the basement of the house.

❖ Hot water is utilized to heat or cool the house by adjusting the automatic valve.

Photosynthesis production of energy sources:

❖ Solar energy can be transferred into chemical energy in plants and trees through photosynthesis, which is the basis of the world"s fossil fuels.

Solar power plant:

❖ It is known that only a fraction of the energy radiated by the sun reaches the earth. But in the

atmosphere radiation will be more.

❖ Satellite revolving around the earth will receive energy for all the 24 hours and will not affected by the weather condition.

❖ The solar panels are installed on the satellite, may vary in area from 16 to 100 square meter based on plant capacity.

❖ The solar cells generates DC electric power and transmit it by means of microwaves [10cm in wavelength, 2-3 GHz in frequency], keeps the losses at minimum and this energy will be converted into high voltage DC or commercial frequency electric power.

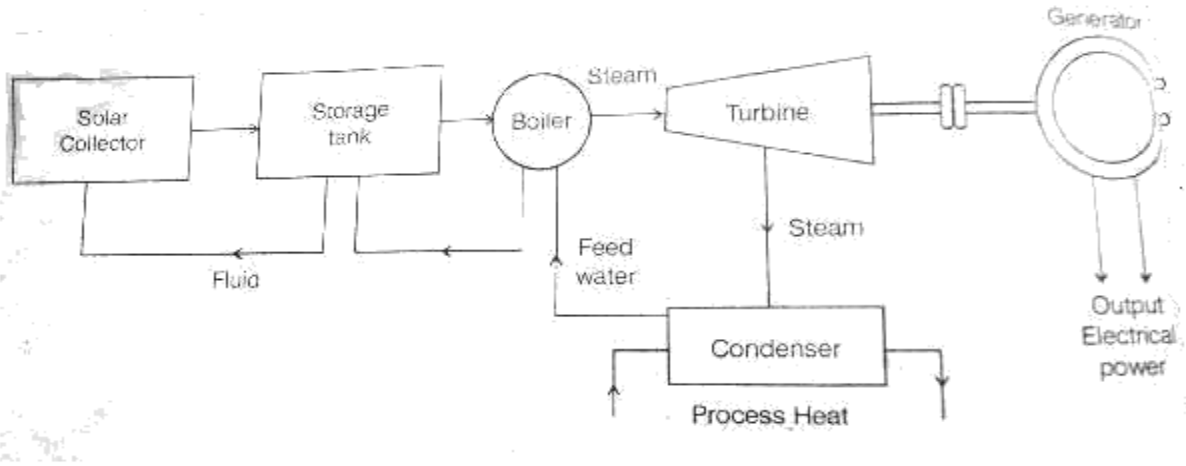


Fig 5.2Block diagram of solar power plant

❖ The antenna is used for transmission [1km in diameter in sending end and 7-10km in diameter in receiving end] with 55 to 75% of efficiency.

❖ The solar cells operates on the principle of photo electricity that is electrons are liberated from the surface of a body when light is incident on it.

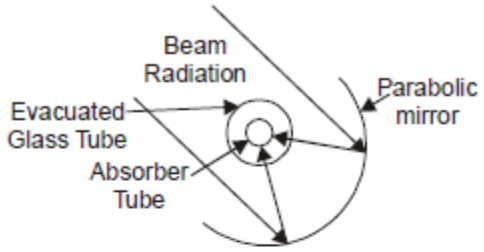


Fig. 2.13. Distributed (Parabolic) Solar Collector.

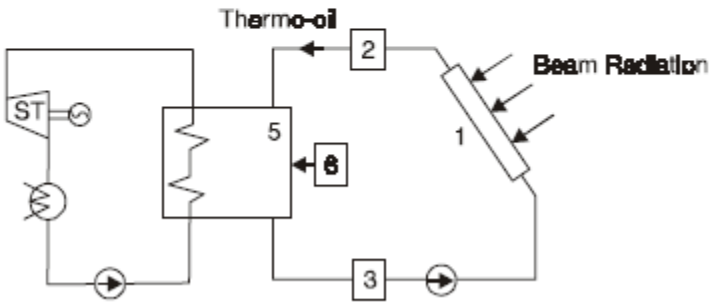


Fig. 2.14. Distributed (Parabolic) Trough Solar Power Plant.

The solar cells in space will be used for long duration; hence the cells are actuated by both sun rays and diffuse light. In cold weather, the decreased luminous flux is compensated by higher efficiency.

❖ Hence efficiency increases with decrease in temperature. [15-20% in efficiency].

❖ Even though sun energy available is free of cost, the fabrication coat and installation of system is too high, so plastic materials are being used more.

❖ The efficiency of solar cells depends on efficiency of collection of solar energy using working fluid (air, water etc).

❖ There are 2 main classes of collectors.

i. Solar concentrators and
ii. Flat plate collector.

Solar concentrators:

❖ It is collecting device having high flux on the absorber surface than flux impinging on concentrator surface.

❖ Optical concentration is by reflecting, refracting elements, positioned to concentrate the incident flux onto a suitable absorber.

❖ Due to apparent motion of the sun, it will be in position to redirect the sun rays onto the absorber if they are stationary, so it needs a tracking device.

❖ A solar concentrator consists of

i. Reflecting or refracting surface
ii. An absorber
iii. Fluid flow system to carry the heat
iv. Cover around absorber
v. Insulation for the unirradiated portion of the absorber.
vi. Self supporting structural capacity and well adjusted tracking mechanism.

Flat plate collector:

❖ Flat plate solar collectors are majorly divided into two types.

❖ They are:

1. Liquid heating collectors
2. Air heating or solar air heaters.

The characteristics features of flat plate collector are:

1. It absorbs both beam and diffuse radiation.
2. It can function without the need for sun tracking.
3. It is simple in construction and requires little maintenance.

1.Liquid Heating Collectors:

❖ It is used for heating water and non – freezing solutions.

❖ The constructional details of simple flat plate collector are shown in figure Q 1. The flat plate collectors have five main components.

❖ They are:

1. Transparent cover (one or two sheets) of glass or plastic.
2. Blackened absorber plate usually of copper, aluminum or steel, typically 1 – 2 mm thick.
3. Tubes (typically 1 – 2 cm diameter), channels or passages, in thermal contact with the absorber plate. In some designs, the tubes form integral part of absorber plate.
4. Thermal insulation, typically 5 – 10 cm in thickness.
5. Tight container to enclose the above components.

❖ As solar radiation strikes on a specially treated absorber plate, it is absorbed and raised its temperature.

❖ This raised heat is transferred to heat transfer fluid circulating in the tube (or channels) with the absorber plate and in intimate contact with it.

❖ Thermal insulation prevents heat loss from the rear surface of the collector.

❖ The upper glass cover perm it"s the entry of solar radiation as it is transparent for incoming short wavelengths, but it is largely opaque to the longer infrared radiation reflected from the absorber.

❖ The glass cover also prevents heat loss due to convection by keeping the air stagnant. The glass cover may reflect about 15% of incoming solar radiation, which can be reduced by applying anti – reflective coating on the outer surface of the glass.

❖ The absorber plate is usually made from a metal sheet 1 to 2mm in thickness, while the tubes which are also of metal, and range in diameter from 1 to 1.5cm.

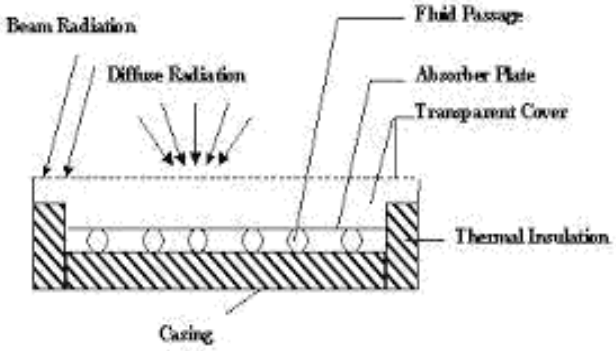


Fig.1 Liquid Flat-plate Collector

❖ Due to low collection efficiency of flat plate collectors, it is uneconomical to arrange sun – tracking.

❖ Hence, a fixed type installation is preferred. The axis of the pipes is placed parallel to the parallel lines of longitude passing through the north and south poles.

❖ The efficiency of the collector system is adversely affected by the shadow, cosine loss, dust etc.

2. Solar Air Heaters:

❖ Figure shows a schematic diagram of solar air heaters, where an air stream is heated by the back side of the collector plate.

❖ Fins attached to the plate increase the contact surface. In this, the back side of the collector is heavily insulated with mineral wool or some other material. The favorable inclination angle to the horizontal is 15° for heating.

❖ Basically, air heaters are classified into two types.

❖ They are:

1. Solar air heater with non – porous absorber.
2. Solar air heater with porous absorber.

❖ In a non – porous type, the air stream does not flow through the absorber plate. Air may flow above and / or behind the absorber plate.

❖ In a porous type, the absorber that includes slit and expanded metal, transpired honey comb and over – lapped glass plate absorber.

❖ The performance of air heaters is improved by:

1. Roughing the rear of the plate to promote turbulence and improve the convective heat transfer co – efficient (or)
2. Increasing the heat transfer surface by adding fins.

Advantages of Solar Energy.

1. Solar energy is free from pollution
2. They collect solar energy optically and transfer it to a single receiver, thus minimizing thermal-energy transport requirements
3. They typically achieve concentration ratios of 300 to 1500 and so are highly efficient both in collecting energy and converting it to electricity.
4. The plant requires little maintenance or help after setup
5. It is economical

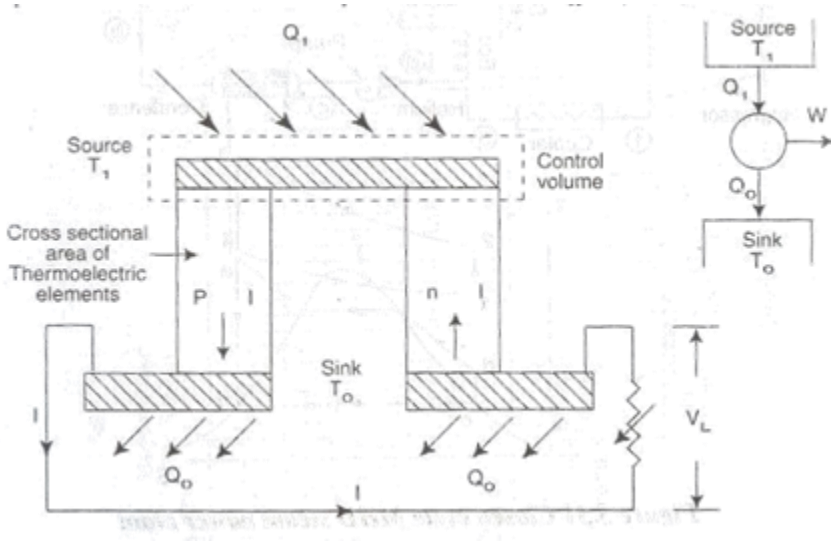
Disadvantages of Solar Energy.

1. Available in day time only
2. Need storage facilities
3. It needs a backup power plant
4. Keeping back up plants hot includes an energy cost which includes coal burning.

12.Explain the working principle of thermoelectric power generation.

❖ It is similar to a thermocouple with the difference that the thermo elements are made up of semi conductors P and N, heat is given to the hot junction and the heat is removed from the cold junction.

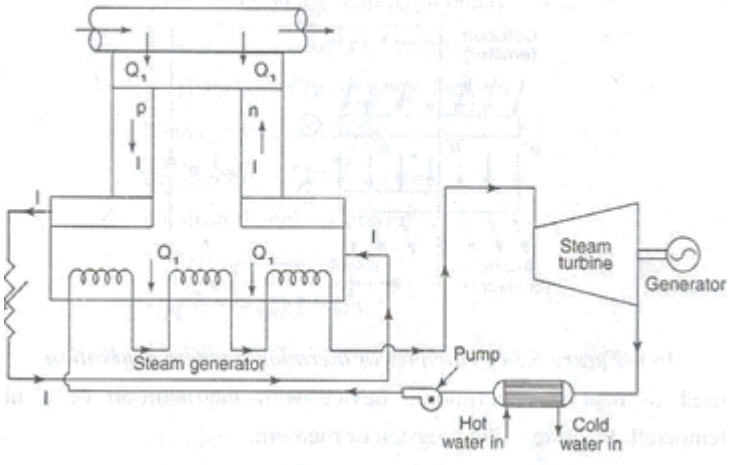
❖ (The thermocouple principle is when the junctions of two dissimilar wires A and B are maintained at two different temperatures, a potential difference is developed called See back effect).



❖ Here applying the first law of thermodynamics to the upper plate as control volume, $T_i T_o$ will generate a see back voltage. Both junctions are made up of copper element

❖ To obtain large outputs, the thermoelectric generator can be incorporated in the fuel elements of nuclear reactors. This is shown in

/

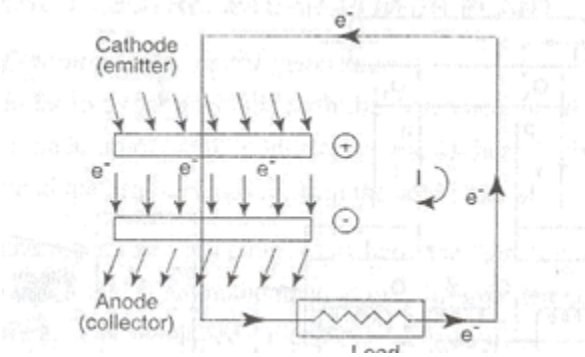


❖ The waste heat of gas turbines and diesel engines can be utilized for thermo electric power generation. By operating with a higher temperature range, the overall efficiency would be higher.

14. Explain the working principle of THERMIONIC-STEAM power generation (May/June 2012)

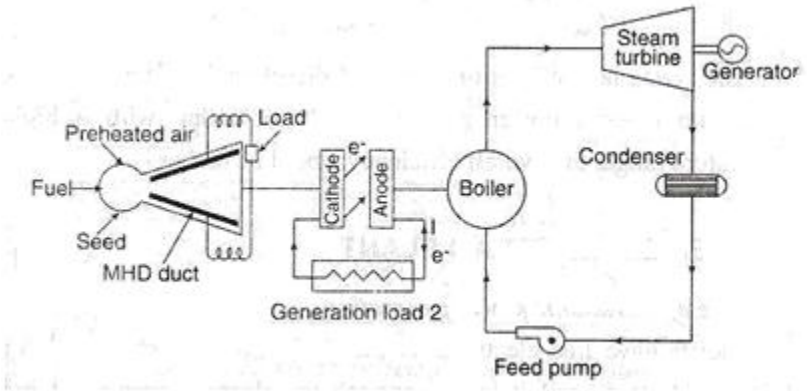
Principle of thermionic power generation:

- ❖ **Metals have free electrons. A metal** electrode which is called an *emitter* is heated until it is hot enough to release electrons from its surface.
- ❖ This electron crosses a small gap and is stored on a cooled metal electrode called *collector*.
- ❖ To reduce the energy loss, the gap is maintained with vacuum space. The electrons enter the collector and return through an external load to the emitter by producing electrical power.
- ❖ The thermionic generator transforms heat directly into power. The below figure shows a combined MHD generator with a thermionic generator



Principles of thermionic power generation

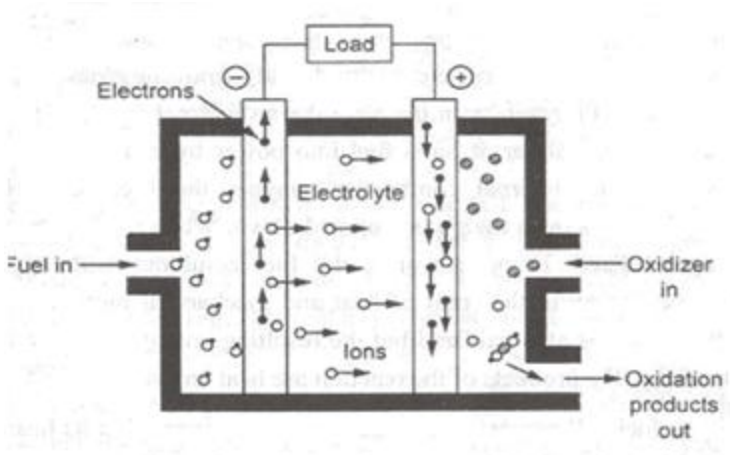
- ❖ It is used to heat the thermionic device with the addition of a high temperature emitters like tungsten or rhenium



15. Briefly Explain the Working principle of a Fuel cell and discuss the choice of fuels required. (May/June 2012,13,Dec 12,13) or What are the various kinds of fuel cell and explain the working ? .(Nov/dec 15) or Enumerate the advantage of fuel cell power source with specific reference to environment.(may/june 16)(Nov/Dec 2016) (APR/MAY 2018)

Fuel Cell:

- ❖ A fuel cell is an electrochemical device in which the chemical energy of a conventional fuel is converted directly and efficiently into low voltage, direct-current electrical energy.
- ❖ One of the chief advantages of such a device is that because the conversion, at least in theory, can be carried out isothermally, the Carnot limitation on efficiency does not apply.
- ❖ A fuel cell is often described as a primary battery in which the fuel and oxidizer are stored external to the battery and fed to it as needed.



- The above figure shows a schematic diagram of a fuel cell. The fuel gas diffuses through the anode and it oxidized, thus releasing electrons to the external circuit.
- The oxidized fuel diffuses through the cathode and is reduced by the electrons that have come from the anode by way of the external circuit.
- The fuel cell is a device that keeps the fuel molecules from mixing with the oxidizer molecules, permitting, however, the transfer of electron by a metallic path that may contain a load of the available fuels, hydrogen has so far given the most promising results, although cells consuming coal, oil or natural gas would be economically much more useful for large scale applications.
- Some of the possible reactions are;

Hydrogen/oxygen 1 . 23 V $2 H_2 + 0_2$ --- > $2 H_2 0$

Hydrazine 1.56 V $N_2H_4 + 0 > 2 H_20 + N_2$

Carbon (Coal) 1.02 V $C + 0_2$ - - - > $C O_2$

Methane 1.05 VC H_4 $+ 2 0_2$ - - - > $C O_2 + 2 H_2 0$

- A fuel cell produces electricity directly from the reaction between hydrogen and oxygen from the air.
- Like an internal combustion engine in a conventional car, it turns fuel into power by causing it to release energy.
- In an internal combustion engine, the fuel burns in tiny explosions that push the pistons up and down.
- When the fuel burns, it is being oxidized. In other words, the fuel combines with oxygen to produce energy in the form of heat and mechanical motion.
- In a fuel cell, the fuel is also oxidized but the resulting energy takes the form of electricity. By-products of the reaction are heat and water.
- A fuel cell power system has many components but its heart is the fuel cell stack, which is made of many thin, flat cells layered together. Each cell produces electricity and the output of all cells is combined to get more power.
- Fuel cells have the potential to revolutionize the way we power our nation, offering cleaner, more-efficient alternatives to the combustion of gasoline and other fossil fuels.
- A fuel cell is a device that uses hydrogen and oxygen to create an electric current.
- The amount of power produced by a fuel cell depends on several factors, including fuel cell type, cell size, the temperature at which it operates, and the pressure at which the gases are supplied to the cell.
- A single fuel cell produces enough electricity for only the smallest applications.
- Therefore, to provide the power needed for most applications, individual fuel cells are combined in series into a fuel cell stack. A typical fuel cell stack may consist of hundreds of fuel cells.

Parts of a Fuel Cell

1. Membrane electrode assembly

- The electrodes (anode and cathode), catalyst, and polymer electrolyte membrane together form the membrane electrode assembly (MEA) of a PEM fuel cell.

Anode:

- The anode, the negative side of the fuel cell, has several jobs. It conducts the electrons that are breed from the hydrogen molecules so that they can be used in an external circuit.
- Channels etched into the anode disperse the hydrogen gas equally over the surface of the catalyst.

Cathode:

- The cathode, the positive side of the fuel cell, also contains channels that distribute the oxygen to the surface of the catalyst.
- It conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

Polymer electrolyte membrane:

- The polymer electrolyte membrane (PEM) is a specially treated material that looks something like ordinary kitchen plastic wrap which conducts only positively charged ions and blocks the electrons.
- The PEM is the key to the fuel cell technology. It will permit only the necessary ions to pass between the anode and cathode. 'Other substances passing through the electrolyte would disrupt the chemical reaction

2. **Catalyst**

- All electrochemical reactions in a fuel cell consist of two separate reactions such as an oxidation half-reaction at the anode and a reduction half-reaction at the cathode.
- Normally, the two half-reactions would occur very slowly at the low operating temperature of the PEM fuel cell.
- So, each of the electrode is coated on one side with a catalyst layer that speeds up the reaction of oxygen and hydrogen.
- It is usually made of platinum powder very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen.
- The platinum-coated side of the catalyst faces the PEM. Platinum-group metals are critical to catalyzing reactions in the fuel cell, but they are very expensive.

2. Chemistry of a Fuel Cell

Anode side: $2H_2 \Rightarrow \mathbf{4H^+ + 4e^-}$

Cathode side:

$0_2 + \mathbf{4H^+} + 4e^- \Rightarrow 2H_20$ Net reaction:

$2H_2 + 0_2 \Rightarrow 2H_20$

- The pressurized hydrogen gas (H_2) enters the fuel cell on the anode side. This gas is forced through the catalyst by the pressure.
- When an 1^-12 molecule comes in contact with the platinum on the catalyst, it splits into two H^+ ions and two electrons (C).
- The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.
- Meanwhile, on the cathode side of the fuel cell, oxygen gas (0_2) is forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H^- ions through the membrane where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H20).

- This reaction in a single fuel cell produces only about 0.7 volts. To get this voltage upto a reasonable level, many separate fuel cells must be combined to form a fuel-cell stack.

3. Hardware

- The backing layers, flow fields, and current collectors are designed to maximize the current from a membrane/electrode assembly.
- The backing layers one next to the anode, the other next to the cathode are usually made of a porous carbon paper or carbon cloth, about as thick as 4 to 12 sheets of paper. The backing layers have to be made of a material that can conduct the electrons that leave the anode and enter the cathode.
- The porous nature of the backing material ensures effective diffusion of each reactant gas to the catalyst on the membrane/electrode assembly.
- The gas spreads out as it diffuses so that when it penetrates the backing, it will be in contact with the entire surface area of the catalyzed membrane.
- The backing layers also help in managing water in the fuel cell; too little or too much water can cause the cell to stop operating.
- Water can build up in the flow channels of the plates or can clog the pores in the carbon cloth preventing reactive gases from reaching the electrodes.
- Each plate also acts as a current collector. Electrons produced by the oxidation of hydrogen must:

1. Be conducted through the anode, through the backing layer, along the length of the stack, and through the plate before they can exit the cell.
2. Travel through an external circuit, and
3. Re-enter the cell at the cathode plate. With the addition of the flow fields and current collectors, the PEM fuel cell is complete only a load-containing external circuit such as an electric motor is required for electric current to flow.

Types of Fuel Cells

1. Hydrogen-oxygen fuel cell
2. Polymer Electrolyte Membrane (PEM) Fuel Cell
3. Direct Methanol Fuel Cell
4. Alkaline Fuel Cell
5. Phosphoric Acid Fuel Cell
6. Molten Carbonate Fuel Cell
7. Solid Oxide Fuel Cell
8. Regenerative Fuel Cell

- Fuel cells have the potential to replace the internal combustion engine in vehicles and provide power for stationary and portable power applications.
- They can be used in transportation applications such as powering automobiles, buses, cycles, and other vehicles.
- Many portable devices can be powered by fuel cells, such as laptop computers and cell phones. They can also be used for stationary applications such as providing electricity to power homes and businesses.

Advantages of Fuel Cell

1. Cost

- It is too early to estimate the cost of the first retail fuel cell vehicles. Incentives and rebates may be necessary to help in reducing the initial purchase price of these vehicle.

2.Operational performance

- Fuel cell vehicles are being developed to meet the performance expectations of today's consumers. These vehicles are expected to be extremely quiet and have very little vibration

due to absence of IC engines and heavy moving parts.

3. Safety

- ❖ The goal is to develop fuel cell vehicles with levels of safety and comfort that are comparable to those of conventional vehicles. If used, high-pressure hydrogen tanks will be designed for maximum safety to avoid rupture.

Problems with Fuel Cells

- ❖ Although the potential benefits of fuel cells are significant, many challenges, technical and otherwise, must be overcome before fuel cells will be a successful, competitive alternative for consumers.
- ❖ These include cost, durability, fuel storage and delivery issues, and public acceptance. Still, scientists and industry are hard at work to overcome these challenges and bring hydrogen and fuel cells to the marketplace.
- ❖ Fuel cell uses oxygen and hydrogen to produce electricity. The oxygen required for a fuel cell comes from the air. In fact, in the PEM fuel cell, ordinaryair is pumped into the cathode. The hydrogen is not so readily available.
- ❖ Hydrogen has some limitations that make it impractical for use in most applications.
- ❖ Hydrogen is difficult to store and distribute, so it would be much more convenient, if fuel cells could use fuels that are more readily available. This problem is addressed by a device called a *reformer*.

Hybrid Fuel Cells

- ❖ In a hybrid fuel cell system, high-temperature fuel cells are coupled with other power generation systems, such as gas turbine, reciprocating engine or other type of fuel cell.
- ❖ The hybrid arrangement allows rejected thermal energy and residual fuel from a high-temperature fuel cell to be used to drive a gas turbine, for example.
- ❖ Preliminary studies show that hybrid systems can maintain extremely low emissions, while achieving fuel efficiencies far beyond the reach of one technology alone.

Advantages of Fuel Cells

6. Conversion efficiencies are very high.
7. Require little attention and less maintenance.
8. Can be installed near the use point, thus reducing electrical transmission requirements and accompanying losses.
9. Fuel cell does not make any noise.
10. A little time is needed to go into operation.
11. Space requirement considerably less in comparison to conventional power plants.

Disadvantages of Fuel Cells

1. High initial cost.
2. Low service life.

16. Explain principle and construction of Biogas? Or write a note on Bioenergy .(Nov/dec 15)(May/ June 17) (APR/MAY 2018)

Principle:

- ❖ Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH4) and carbon dioxide (CO2) it is a renewable fuel produced from waste treatment.
- ❖ **Anaerobic digestion**is basically a simple process carried out in a number of steps by many different bacteria that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra.

- ❖ Humans tend to make the process as complicated as possible by trying to improve on nature in complex machines, but a simple approach is still possible.

Components of the biogas unit

The components of a biogas unit are:

1. Reception tank
2. Digester or fermenter
3. Gas holder
4. Overflow tank

Size of biogas unit

The size of a biogas unit depends on several factors, which are:

1.The amount and type of organic waste to be disposed in the digester

2.The objective of treating the organic waste (the production of energy and/or organic fertilizer)

3.Demand of natural gas and consumption pattern

4.On-site nature of the soil and the level of ground water

5.Air temperature in the region and wind direction throughout the different seasons

6.The training level of the staff on farm and home regarding operation of biogas units

- ❖ The amount of manure fed into a digester each day has an important effect on its operation.
- ❖ This is measured by volume added in relation to the volume of the digester, but the actual quantity fed to the digester also depends onthe temperature at which the digester is maintained.
- ❖ In order to determine the unit sizeof a biogas unit, the following mathematical equation must be achieved:

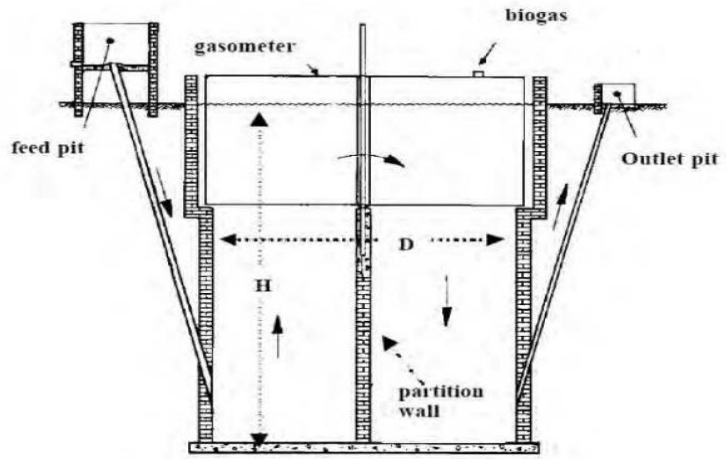
  Digester size (m^3) = Daily feed-in (m^3 day-1) × Retention time(day) (1)
- ❖ The digester size can be defined as the total size of the biogas unit, which includes the effective size of any volume occupied by the fermented material and the volume of gas storage.
- ❖ Size of the daily feed-in is the size of a mixture of dung with water added to the digester once daily or several times and the average concentration of total solids of 10%, where mixing the organic wastes with water depends on its water content.

Types of digester

- ❖ During the last century a number of different types of flows in simple digester have been developed and they can be of the following kinds: (1) batch flow, (2) continuous flow, (3) continuously expanding, (4) plug flow, and (5) contact flow.

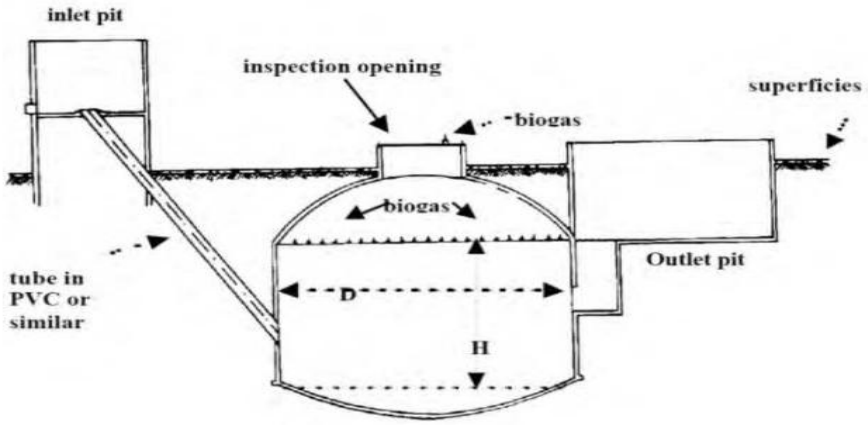
Indian digester:

- ❖ The digester is made using burnt-clay bricks and Biogas cement. The cylindrical dome is made of metal sheets and moves up and down as it stores and releases the biogas.
- ❖ The digester is operated in continuing method and often vertically, almost cylindrical built.
- ❖ This type is suitable for the homogeneous materials, as for the animals' excrements that do not tend to build sinking layers.
- ❖ The green waste must be split. If it is mixed with huge allotments, then it will threat the digester with blockage.



Chinese digester

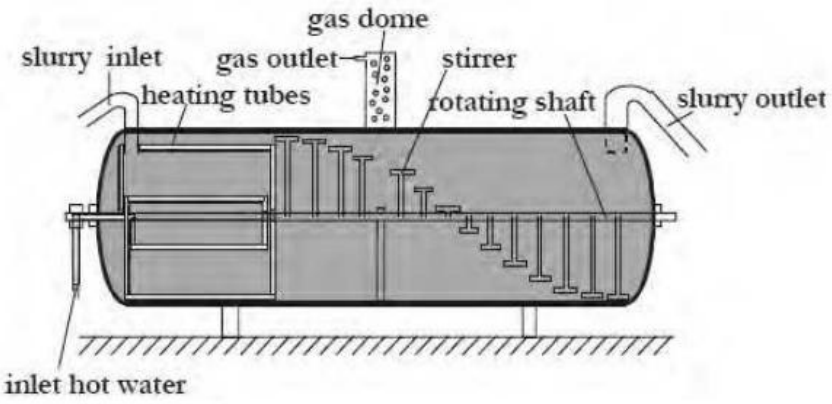
- The Chinese-type model digester is comprised of a cylindrical body, two spherical domes, inlet pit, outlet pit and an inspection opening (Florentine, 2003).
- The digester is made using cement and bricks and it is a permanent structure. Just as in the Indian digester this has two drains to feed waste and to collect the composted waste.
- The biogas is collected in the upper chamber and the waste decomposes in the lower chamber



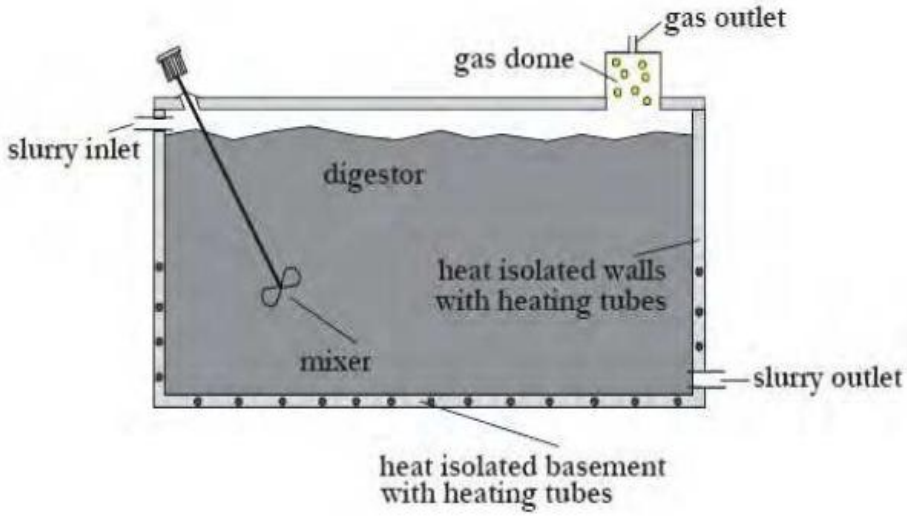
- If the gas pressure exceeds the atmospheric pressure (1 bar) and there is no gas extracted from the dome, then the rot substrate squeezed from the reactor into the filled pipe, but often in the pool of counterpoise.

Operation:

- The most common digester design is cylindrical. Digesters can be classified in horizontal and vertical designs.
- Currently, vertical concrete or steel digesters with rotating propellers or immersion pumps for homogenization are widespread.
- Vertical tanks simply take feedstock in a pipe on one side, whilst digestate overflows through a pipe on the other side.
- In horizontal plug-flow systems, a more solid feedstock is used as a plug that flows through a horizontal digester at the rate it is fed-in.
- Vertical tanks are simpler and cheaper to operate, but the feedstock may not reside in the digester for the optimum period of time.
- Horizontal tanks are more expensive to build and operate, but the feedstock will neither leave the digester too early nor stay inside the digester for an uneconomically long period.



Anaerobic digesters can be built either above orunder the ground. An alternative is that a part of the digester can be buried.



- ❖ Anaerobic digesters constructed above ground are steel structures to withstand the pressure; therefore, it is simpler and cheaper to build the digester underground
- ❖ Maintenance is, however, much simpler for digesters built above ground and a black coating will help provide some solar heating

17. A 10m/s wind is at 1 standard atmosphere and 15 degree Celsius. Calculate:

- **The Total power density in the wind stream**
- **The maximum obtainable power density**
- **A reasonably obtainable power density**
- **Total power produced if the turbine diameter is 120m.**
- **Turbine power output (NOV/DEC 2017)**

Solution. The air density,

$$\rho = \frac{P}{RT}$$

$$= (1.01325 \times 10^5)/[287\ (15 + 273)] = \mathbf{1.226\ kg/m^3}.$$

1. Total power density

$$\frac{\rho_{total}}{A} = \frac{\rho V_i^3}{2}$$

$$= 1.226 \times (10)^3/2 = \mathbf{613\ W/m^3}$$

2. Maximum power density

$$\frac{\rho_{max}}{A} = \frac{8}{27}\rho V_i^3$$

$$= (8/27) \times 1.226 \times (10)^3 = \mathbf{363\ W/m^3}.$$

3. Assuming $\eta = 40\%$

Actual power density,

$$\frac{P}{A} = 0.4\left(\frac{P_{wt}}{A}\right)$$

$$= 0.4 \times 613 = \mathbf{245\ W/m^3}.$$

4. Total power produced,

$$P = \left(\frac{P}{A}\right)\frac{\pi D^2}{4}$$

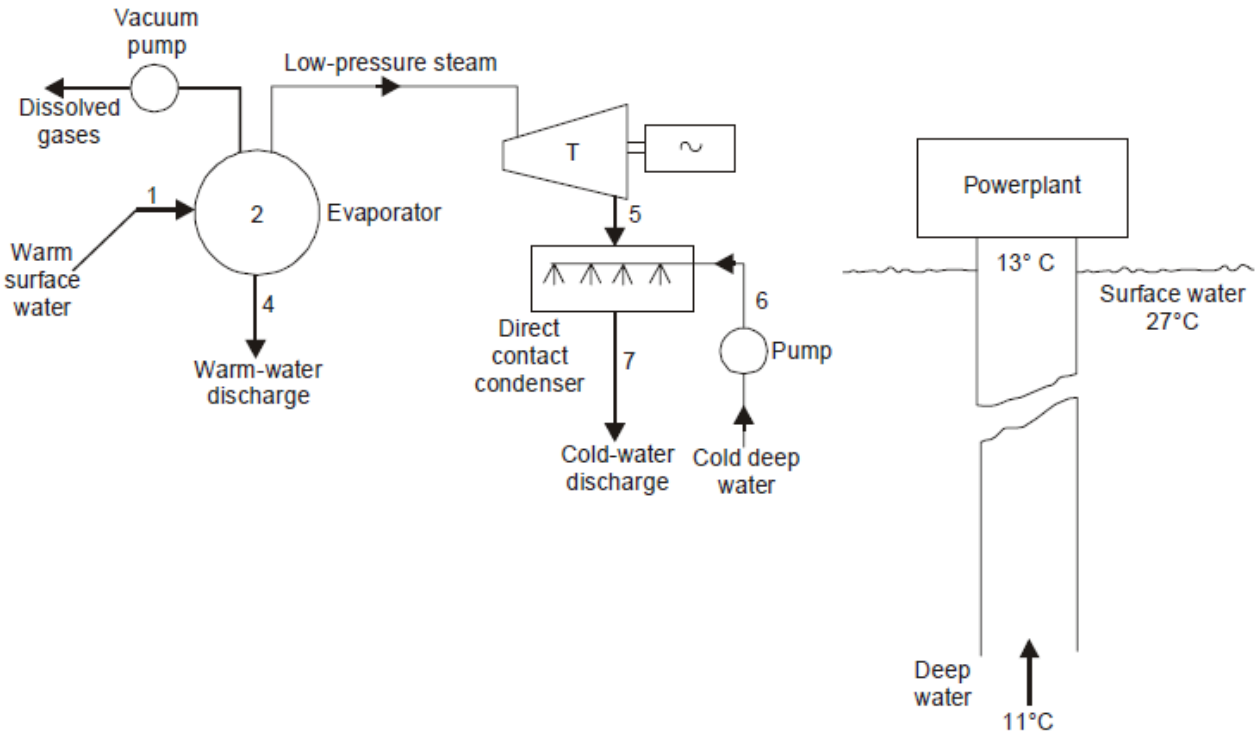
$$= 0.245 \times \pi(120)^2/4 = \mathbf{2770\ kW}.$$

18.Draw the schematic of Anderson cycle based on OTEC and discuss it?(NOV/DEC 2017)

- ❖ Ocean thermal energy is used for many applications, including electricity generation. There are three types of electricity conversion systems: closed-cycle, open-cycle, and hybrid.
- ❖ Closed-cycle systems use the ocean's warm surface water to vaporize a working fluid, which has a low-boiling point, such as ammonia. The vapor expands and turns a turbine. The turbine then activates a generator to produce electricity.
- ❖ Open-cycle systems actually boil the seawater by operating at low pressures. This produces steam that passes through a turbine/generator. Hybrid systems combine both closed-cycle and open-cycle systems.
- ❖ Depending Upon these electricity conversion systems the Ocean power plant can be divided mainly in to two groups.

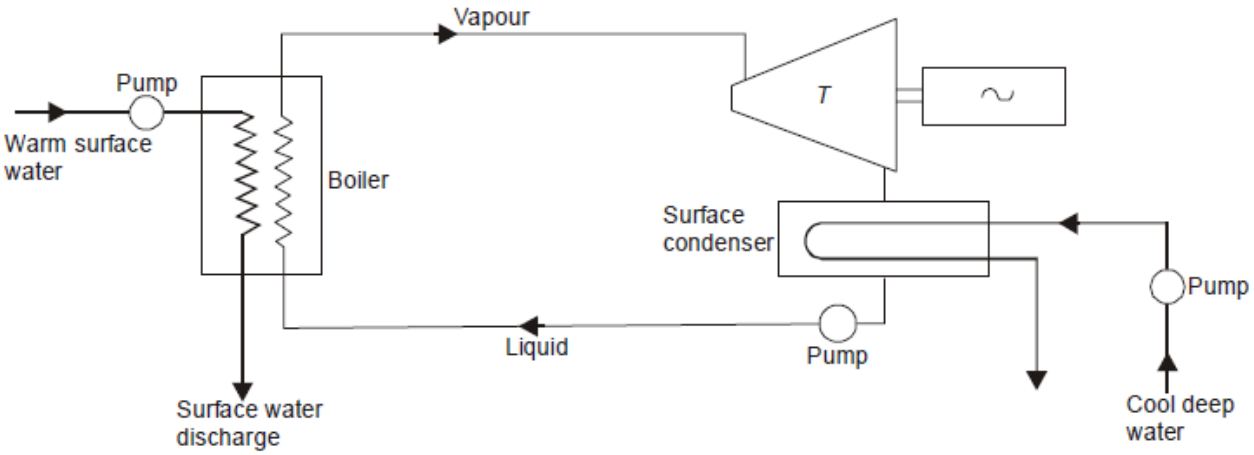
The Open or Claude OTEC Cycle Power Plant:

❖ The Claude plant used an open cycle in which seawater itself plays the multiple role of heat source, working fluid, coolant, and heat sink.



- In the cycle warm surface water at 27°C is admitted into an evaporator in which the pressure ismaintained at a value slightly below the saturation pressure corresponding to that water temperature.
- Water entering the evaporator, there four, finds itself "superheated" at the new pressure.This temporarily superheated water undergoes volume boiling causing that water to partiallyflash to steam to an equilibrium two-phase condition at the new pressure and temperature.
- The low pressure in the evaporator is maintained by a vacuum pump that also removes the dissolved noncondensable gases from the evaporator.

The Closed or Anderson, OTEC Cycle Power Plant:



- d'Arsonval's original concept in 1881 was that of a closed cycle that also utilizes the ocean's warm surface and cool deep waters as heat source and sink, respectively, but requires a separate working fluid that receives and rejects heat to the source and sink via heat exchangers (boiler and surface con-denser).

- The working fluid may be ammonia, propane, or a Freon. The operating (saturation) pressures of such fluids at the boiler and condenser temperatures are much higher than those of water, being roughly 10 bar at the boiler, and their specific volumes are much lower, being comparable to those of steam in conventional power plants.

Question Bank

PART A

1. What is the use of surge tank? (May/June 2012)(pg.no:2)
2. What is the main purpose of the dam?(Nov/Dec 2012) (pg.no:3)
3. What is hydrograph? [MAY/JUN 2013] (pg.no:3)
4. Write short notes on Micro Hydel plant? [MAY/JUN 2012],[MAY/JUNE 2007] (pg.no:3)
5. On what basis hydraulic turbines are selected? [NOV/DEC 2012] (pg.no:3)
6. Why surge tank important in hydro power plant?[APR/MAY 2010] (pg.no:3)
7. List any four advantages and disadvantages of hydro power: (May/June 2013) (pg.no:4)
8. List the factors to be considered for the selection of site for hydro power plant. Or What are the different factors to be considered while selecting the site for hydro electric power plant?(may/june 15) (pg.no:4)
9. What is a surge tank? Or What for surge tank is provided in the hydel plant? (May/June 2012) or what is surge tank?why it is important in hydro power plants?(nov/dec 14) (pg.no:5)
10. What is the function of Draft tube? (May/June 2012) (pg.no:5)
11. What are mini and micro Hydro plants? (may/june 15) (pg.no:6)
12. Define turbines and its types.(nov/dec 14) (pg.no:6)
13. For which hydro projects are developed. (Nov/Dec 2013) (pg.no:7)
14. What is meant by water hammer.(may/june14) (pg.no:7)
15. Classify the hydro-electric turbines with respect to high medium and low head.(Nov/Dec 2012). (pg.no:7)
16. What is draft tube? (Anna Univ. April 2005) (pg.no:7)
17. What are three main factors for power output of hydroelectric plant?(Anna Univ.Apil 2005) (pg.no:7)
18 . What is significance of specific speed of hydraulic turbines?(Anna Univ. June 2009)? (pg.no:7)
19. Define Unit speed of turbine (Anna Univ. November 2003)
20. On What factors does the selection of a water turbine for hydel plants depend upon? (May/June 2012) (pg.no:7)
21.Differntiate storage with pondage.(may/june 14) (pg.no:9)
22. List the various types of solar energy collectors. Or what are the types of solar collector.(Nov/Dec 14) (pg.no:9)
23. What is a solar cell? (May/June 2012, Dec 12) (pg.no:9)
24.What are the types of collectors used in solar power generation? Or What are the types of solar collector?(Nov/dec 14) (pg.no:9)
25.Mention the factors which determine the power in wind. (April/May-2007)(pg.no:9)
26.What is the principle of geo thermal power generation? (april/may 2010) (pg.no:10)
27. Define the term gust in a wind energy system. (NOV/DEC-2012) (pg.no:11)
28. Define Co-efficient of performance with respect to wind mill. (April/May-2009) (pg.no:12)
29.What are the different sources of geothermal energy? (Dec 12, May 13) (pg.no:12)
30.Whatunderstand by zero energy houses? (May 13) (pg.no:13)
32. Define law of conservation of energy. (Dec 13) (pg.no:14)

33.Give example of geothermal is the principle of a thermoelectric power generator? (May/June 2012)) (pg.no:12)
31.What do you
resources?(Nov/dec 14) (pg.no:14)
34.Enumerate the factors affecting the suitability of the site for the tidal power plant.(May/june 15) (pg.no:14)
35.What is the principle of OTEC plant?(May/june 14) (pg.no:14)
36.What is biogas? Give the advantages. (Nov/Dec 16)
37.Differentiate Francis turbine and Kaplan turbine. (Nov/Dec 16)

PART B

1.Explain layout of hydel power plant (or) With a simple Diagram, explain the essential features of hydro power plant. (Nov/Dec 2013) or Explain the arrangement of the components of the hydro electric power plant with neat sketch.(may/june 14) (pg.no:14)
2. i) How the hydro power is classified? (ii) What are the differences between high head power plant and pumped storage power plants? Explain with a neat sketch. [Nov/Dec-2012,13][May/June 2012,2013]Classification of hydel power plants depends on following factors or classify the hydro electric plants according to availability of heat and nature of load.(may/june 15) (pg.no:17)
3.Discuss the pumped storage hydel plant with neat sketches and high light their
advantage.(may/june 15,nov/dec 14) or Describe pumped storage powerplant with neat
diagram.(may/june 14)
4. What is the basis for selecting a site for hydro power plants? Explain. (Dec 2012) (pg.no:20)
5.Describe the various types of hydraulic turbines in hydro plants.(Nov/Dec 2012) or Write about selection of water turbine?Explain any one turbine with neat sketch used in hydro electric power plant?(nov/dec 14) (pg.no:21)
6. Explain the working of Francis turbine with Pelton wheel and give its merits and demerits (Nov/Dec 2013) (pg.no:22)
7.Explain the working of Pelton wheel turbine and give its merits and demerits (Nov/Dec 2013) (pg.no:25)
8. Explain the working of Kaplan turbine and give its merits and demerits (or) Compare and contrast Kaplan turbine with Francis turbine. (May/June 2012) (pg.no:27)
9.With neat sketch explain the working of wind power plant. (Nov/Dec 2009,
April/May 2010,11) (pg.no:29)
10. Explain the main components and working of tidal power plant. (Nov/Dec -2012, May/June – 2013) (pg.no:32)
11.Explain in detail about the working of geothermal power plant. Or Explain about Hot Springs and Steam Ejection (May/June – 2012) (Nov/Dec 2013) (pg.no:36)

PART A

1.What do you mean by Economics of power generation?

❖ The art of determining the per unit i.e. one KWh cost of production of electrical energy is known as Economics of power generation.

2. Explain the term depreciation.

❖ The decrease in the value of the power plant equipment and building due to constant use is known as depreciation.

❖ In practice, every power station has a useful life ranging from fifteen to thirty years.

❖ From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of the plant. This reduction in the value of plant every year is known as annual depreciation.

3. Define load factor.(may/june16)

❖ Load factor is the ratio of average demand to the maximum demand during a certain period of time and is applicable to both generating equipment and receiving equipment.

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Maximum demand}}$$

4. Define diversity factor.

❖ Diversity factor is defined as the state of being dissimilar to oneanother. It is defined as the ratio of sum of the maximum demands of individual consuming units in a group during a specified period to the maximum demand of the whole group during the same period.

$$\text{Diversity factor} = \frac{\text{Sum of individual demands of diffrernt units in a group}}{\text{Maximum demand of the entire group}}$$

❖ The value of diversity factor is always greater than one. If the diversity factor is higher, the cost per unit of generation will be lesser.

5. What are the classifications of system load? (May / June 2012)

Residential Load: It consists of domestic lights, fan and other appliances etc., has a high peak during evening.

Commercial Load: It covers offices, hospitals, hotels, shopping complex and theatres etc., has two peaks, mornings and evening.

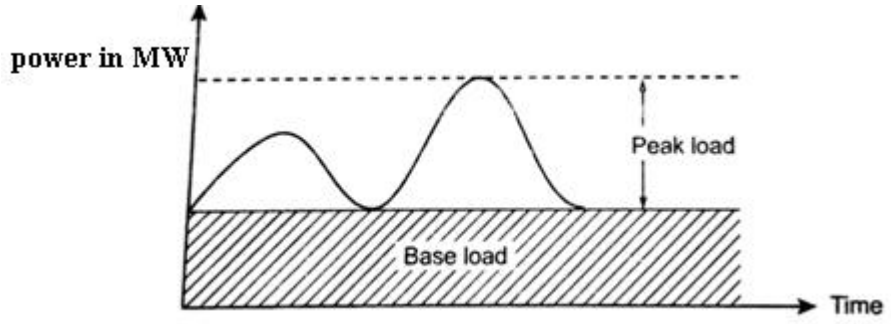
Industrial Load: It covers small and heavy industries working on shifts, so load is constant throughout the day.

Agricultural Load: It occurs during the day time.

Municipal Load: It consists of street-lighting, eater-supply and drainage. Street lighting load remains constant from 6 p.m. to 6 a.m. Fill up the water tank during off-peak hours.

6. What is base load? (April \ May 2008)

❖ It is the load that has been drawn constantly throughout the time. The unvarying load which occurs almost the whole day on the station is known as base load.



7. What is load curve? (Nov/Dec-09)(May/June -12)

❖ The curve showing the variation of load on the power station with reference to time is known as a load curve.

The load curves supply the following information

1. The variation of the load during different hours of the day.
2. The area under the curve represents the total number of units generated in a day.
3. The peak of the curve represents the maximum demand on the station on the particular day.
4. The area under the load curve divided by the number of hours represents the average load on the power station.
5. The ratio of the area under the load curve to the total area of the rectangle in which it is contained gives the load factor.

8. What do you mean by utilisation factor? (APR/MAY 2018)

❖ It is a measure of the utility of the power plant capacity and isthe ratio of maximum demand to the rated capacity of the power plant. It is always less than unity.

Utilization factor = Maximum Demand on the power station/Rated capacity of the power station

❖ A low value of utilization factor indicates that the plant has been installed much in advance of need.

❖ A high value indicates that the plant is probably most efficient in the system. If its value exceeds unity, it means that the load has been carried in excess of rated capacity of the plant.

9. Write short note on load duration curve? (May/June -12)

❖ When the load elements of a load curve are arranged in the order of descending magnitudes, the curve thus obtained is called load duration curve.

❖ The load curve is obtained from the same data as the load curve but the ordinates are arranged in the order of descending magnitudes.

❖ In other words, the maximum load is represented to the left and decreasing loads are represented to the right in the descending order. Hence the area under the load duration curve and the load curve are equal.

❖ Load factor and diversity factor play a vital role in the cost of the supply of electrical energy. Higher the values of load factor and diversity factor, lower will be the overall cost per unit generated.

10. Differentiate between load curve and load duration curve. (Nov/Dec-12)

Load Curve:

❖ Load on the power system is rarely constant. It varies from time to time.

❖ The curve showing the variation of load on the power station with respect to time is known as a load curve.

Load Duration Curve:

❖ This is another type of curve which indicated the variation of load, but with the loads arranged in descending order of magnitude, i.e., the greatest load on the left and lesser loads towards right. From this curve, the load factor of the station can also be determined.

11. Write the significance of load factor?

❖ Higher load factor means greater average load, resulting in greater number of units generated for a given maximum demand.

❖ Thus, the standing charges, which are proportional to maximum demand and independent of number of units generated, can be distributed over a large number of unitssupplied and therefore overall cost per unit of electrical energy generated will be reduced.

12. Why is electrical energy conservation important?(Nov/Dec-2009)

❖ It is important that any energy conservation plan should only try to eliminate wastage of energy without any way affecting productivity and growth rate.

13. What are the methods for determining depreciation charges?

The methods commonly used for determination of annual depreciation charges are

1. Straight line method
2. Diminishing value method and
3. Sinking fund method.

14. What are the objectives of tariff? (Apr/May-2010)(Nov/Dec 2016)

❖ Electrical energy is sold at such a rate so that it not only returns the cost but also earns reasonable profit. Therefore, a tariff must cover the following items:

1. Recovery of cost of capital investment in generating, transmitting and distributing equipment.
2. Recovery of cost of operation, supplies and maintenance of equipment.
3. Recovery of cost of metering equipment, billing, collection costs etc.
4. A satisfactory return on the total capital investment.

15. Define the term connected load factor.

❖ It is the sum of the continuous rating in KW of all electrical devices installed at the consumer's premises and connected to the supply system.

16. Define capacity factor.(may/june16)

❖ It is the ratio of average demand to plant capacity

17. What is plant use factor?

❖ It is defined as the ratio of kwh generated to the product of plant capacity and number of hours for which the plant is in operation.

18. Define tariffs.

❖ The rate at which energy is supplied to a consumer is known as tariff. Tariffs or energy rates are the different methods of charging the consumers for the consumption of electricity. It is desirable to charge the consumer according to the maximum demand and the energy consumed.

19. List out the various types of Tariff.

❖ Simple tariff or uniform rate tariff
❖ Hopkinson demand rate(two part tariff)
❖ Flat demand rate
❖ Straight meter rate
❖ Block meter rate
❖ Wright demand rate
❖ Power factor tariff

20. What is three part tariff?

❖ The total charge comprised of fixed charge made during billing period, charge per kW of maximum demand and charge per kWh of energy consumed.

21. What is the difference between base load and peak load?

❖ The unvarying load which occurs almost the whole day is known as base load.
❖ The various demands of load over and above the base load is the peak load.

22. Define ''Connected load''. (Nov / Dec 2011) (May / June 2013) (May / June 2014)

❖ The sum of the continuous ratings of all the electrical equipment connected to the supply system us known as connected load.

23. Define the term "maximum demand". (Nov / Dec 2012) (May / June 2014)

❖ The greatest of all "short time interval averaged" during a given period on the power station is called the maximum demand.

24. Define load duration curve. (May / June 2013)

❖ This is another type of curve which indicated the variation of load, but with the loads arranged in descending order of magnitude, i.e., the greatest load on the left and lesser loads towards right. From this curve, the load factor of the station can also be determined.

25. What is the effect of load factor on the cost of generation? (May / June 2013)

- ❖ Load factor is always greater than unity, because average load is smaller than maximum demand.
- ❖ It is used to determine the overall cost per unit generated.
- ❖ If the load factor is high, cost per unit generated is low.

26. What is meant by chronological load curve? (May / June 2013) (APR/MAY 2018)

- ❖ A load duration curve represents re-arrangements of all the load elements of chronological load curve in order of descending magnitude.
- ❖ This curve is derived from the chronological load curve. The area under the load duration curve and the corresponding chronological load curve is equal and represents total energy delivered by the generating station.

27. Define Plant use factor. (Nov / Dev 2012) (May / June 2013) (Nov / Dev 2013) (May / June 2014) (Nov/Dec 2016)

- ❖ It is defined as the ratio of the actual energy generated during a given period to the product of capacity of plant and the number of hours the plant has been actually operated during the period.
- ❖ Total KWhr Generated Plant Use Factor = Rated Capacity of the plant Number of operating hours

28. Define Plant capacity factor. (May / June 2013) (Nov / Dec 2013)

- ❖ Plant capacity factor is defined as the ratio of the average load to the rated capacity of the power plant.
- ❖ Average Demand Plant Capacity Factor = Rated Capacity of the power plant Units or KWhrs generated = Plant Capacity Number of Hours

29. Explain Reserve requirements. (Nov / Dev 2012)

- ❖ In any area, the kind of fuel available cost, availability of suitable sites for a hydro station, the nature of load to be supplied, are considered by choosing the type of generation.
- ❖ The minimum capacity of the generating station must be such as to meet the maximum demand.

Installed Reserves: Installed reserve is that generating capacity which is the power intended to be always available. Installed reserve can be kept low by the achievement of good diversity factor.

Spinning Reserves: Spinning reserve is that generating capacity which is connected to the bus and is ready to take load.

Cold Reserves: Cold reserve is that reserve generating capacity which is available for service but is not in operation.

Hot Reserves: Hot reserve is that reserve generating capacity which is in operation bus is not in service.

30 Define spinning reserve. (Or) What is spinning reserve? (Or) What do you mean by spinning reserve? (Nov / Dev 2007) (April \ May 2008) (Nov / Dev 2010) (Nov / Dev 2013)

- ❖ Spinning reserve is that generating capacity which is connected to the bus and is ready to take load.

31. What is installed reserve? (April \ May 2008)

- ❖ Installed reserve is that generating capacity which is the power intended to be always available. Installed reserve can be kept low by the achievement of good diversity factor.

32. Define Hot reserve. (Nov / Dev 2007) (April \ May 2008) (Nov / Dev 2010) (Nov / Dev 2013)

- Hot reserve is that reserve generating capacity which is in operation bus is not in service.

33. Define Cold reserve. (Nov / Dec 2007) (April \ May 2008) (Nov / Dec 2010) (Nov / Dec 2013)

- Cold reserve is that reserve generating capacity which is available for service but is not in operation.

34. What are the major factors that decide the economics of power plants? (May 08)

- The economics of power plant operation is greatly influenced by:
  (a) Load factor
  (b) Demand factor
  (c) Utilization factor

35. What includes fixed cost? Or What are the fixed cost in power plant.(may/june16)

- Fixed cost includes the following cost.

1. Cost of land 2. Cost of building 3. Cost of equipment 4. Cost of installation 5. Interest 6. Depreciation cost 7. Insurance 8. Management cost

36. What is the need of depreciation cost?

- Depreciation cost is the amount to be set aside per year from the income of the plant to meet the depreciation caused by the age of service, wear and tear of the machinery and equipments.
- Depreciation amount collected every year helps in replacing and repairing the equipment.

37.What includes operating cost?

- Operating cost includes the following cost.
  1. Cost of fuel
  2. Cost of operating labor,
  3. Cost of maintenance labors and materials.
  4. Cost of supplier like Water for feeding boilers, for condenser and for general use Lubrication oil and grease, Water treatment chemicals.

38.List the types of Tariffs to calculate energy rate(Dec 2012).

The various types of tariffs are as follows,

(1) Flat demand rate
(2) Straight line meter rate
(3) Step meter rate
(4) Block rate tariff
(5) Two part tariff
(6) Three part tariff

39.What is demand factor?

- Demand factor is defined as the ratio of maximum demand to connected load.
- Connected load is the sum of ratings in kW of equipment installed in the consumer's premises.
- Maximum demand is the maximum load, which a consumer uses at any time.

40.What is the significance of load curve? (Nov/dec 15)

- The load curve provides complete information about the incoming loads thus helping to predict the annual requirements of energy.
- Based on the annual energy consumption ,capacity of the plant to be installed to meet the peak and fluctuating loads can be decided.
- These curves also helps to estimate the generating cost and to decide the operating schedule of the power station i.e, the sequence in which different units to be operated.

41.What are the equipment used to control the particulates. (Nov/dec 15) (NOV/DEC 2017)

Particulate emission:

After burning the fossil fuel in the power plant ,the particulate matter (dust particles)do not settle down and it is carry over along with smoke.

Equipment used to control the particulates:

- Cinder catcher
- Wet scrubbers
- Electrostatic precipitator
- Baghouse filter.

42. What is fixed and operating cost? (May/June 17) (NOV/DEC 2017)

a)Fixed cost:

- It includes cost of land, buildings, equipment, transmission and distribution, cost of planning and designing the plant.

b)Running or operating cost:

- It includes the cost of fuel, cost of building, cost of lubricating oil, greases, cooling water,, cost of maintenance and repairs.

43. List down the nuclear waste disposal methods. (May/June 17)

- Disposal in sea
- Disposal in land
- Disposal by reduction process through chemical reaction
- Disposal by solidification process

PART-B

1. What is the cost of Electrical Generation? And its various types of cost associated with Power Generation? Or Name and elaborate on the elements that contribute to the total cost of electricity.(may/june 16) (APR/MAY 2018)

- Total annual operating expenditure of a power station can be classified into

a)Fixed cost:

- It is the cost which is independent of maximum demand and units generated.

b)Semi fixed charges:

- These charges are dependent upon the installed capacity of the plant and are independent of the electrical energy output of the plant.

c)Running or operating cost:

- These cost depend upon the number of hours the plant is in operation or upon the number of units of electrical energy generated.

Annual cost of power generation in plant:

Total annual cost factor E = a + b kW + c kWh.
→ a, b, c are constants.
Fixed and semi fixed are independent of the amount of energy generated said to be standing cost.
The b and c values will be given from various plants as,

Sl.no	Power plant	Values of b	Values of c
1.	Hydro	Rs. 1500 – 6000/kW	Paisa 25 – 30
2.	steam	Rs. 800 – 1100/kW	Rs. 1.0 – 1.25/kWh
3.	Nuclear	Rs. 4000 – 8000/kW	Paisa 30 – 35/kWh
4.	Diesel	Rs. 500 – 800/kW	Rs. 4.00 – 5.00/kWh
5.	Gas	Rs. 800 – 1800/kW	Rs. 1.50 – 2.00/kWh

2. Explain the methods of calculating the depreciation of an electrical power plant.

Methods of determining depreciation:

- The decrease in the value of the power plant equipment and building due to constant use is known as depreciation. The methods commonly used for determination of annual depreciation charges are.

a) Straight line method:

- In this method, a constant depreciation charge is made every year on the basis of total depreciation.

$$\text{Annual depreciation charge} = \frac{\text{Initial Cost [P]} - \text{Scrap Value [S]}}{\text{Useful life [n]}}$$

- Though this method is very popular (simplicity) but not take into account, the amount of interest earned.
- The assumption of constant depreciation every year is also not correct.

b) Diminishing value or Declining balance method:

- Depreciation rate is fixed for every year. The total expenses on the plant results in distribution over its total useful life. Here depreciation is high – maintenance charge low and depreciation is low – maintenance charge is high late years.

- The value of plant after 1 year

$$S = P\,[1 - X]$$

$$P - \text{cost of the plant}$$

$$S - \text{scrap or salvage value}$$

$$n - \text{useful life of equipment in year}$$

$$X - \text{annual unit depreciation}$$

- The value of plant after 2 years

$$S = P\,[1 - X][1 - X] = P[1 - X]^2$$

- The value of plant after n year,

$$S = P[1 - X]^n \; or [1 - X] = \left[\frac{S}{P}\right]^{1/n} \; or X = 1 - \left[\frac{S}{P}\right]^{1/n}$$

$$\text{Depreciation for the first year} = XP = P\left[1 - \left[\frac{S}{P}\right]^{1/n}\right]$$

$$\text{Depreciation for the second year} = X$$

Drawback:

- At early years, heavy burden towards depreciation charges.
- Amount of interest earned by reserve accumulation is ignored.

c) <u>Sinking fund method:</u>

- In this, fixed depreciation charge is made every year and interest compounded on it annually.
- The constant depreciation charge is total of annual installments plus the interest accumulations equal to the cost of replacement of equipment after its useful life.

P – Initial value of the equipment
n – Useful life of equipment in year
r – Rate of interest per annum [fraction]
q – Annual deposit
rq – annual deposit earns interest in one year.
At the end of one year $\rightarrow q + rq = q(1 + r)$
The end of 2 years $\rightarrow q(1 + r)^2$
$\therefore$ After 'n' years total sinking fund $= q[(1 + r)^{n-1} + (1 + r)^{n-2} + \cdots + (1 + r)]$

$$\text{Total fund} = \text{cost of replacement } (P - S)$$

$$\text{Total fund} = \frac{q(1+r)^{n-1}}{r}$$

$$P - S = \frac{q(1+r)^{n-1}}{r}$$

$\therefore$ Depreciation charge $q = P - S\left[\frac{r}{(1+r)^{n-1}}\right]$

3.Elucidate the objectives and requirements to tariff and general form of tariff.(Nov/dec 15)or List and discuss any 4 power tariff structure adopted by TANGEDCO?(may/june 16) (May/ June 17) (NOV/DEC 2017)(APR/MAY 2018)

Tariff

- The rate of which electrical energy is supplied to a consumer is known as tariff. There are various types of tariffs.

a.Flat demand tariff:

- Ancient one, charged on the basis of number of lamps installed or on the basis of total connected load.
- The use of power restricted to very few applications-lamps.

×is load connected in KW and 'a' – rate per KW/

Energy charges = Rs. a ×.

Advantage:

- Need no metering, billing and accounting costs.
- This tariff is restricted for consumers, but used in street and signal lighting.

b.Simple tariff

- The price charged per unit is constant; energy is recorded by means of an energy meter.
- When there is a fixed rate per unit of energy consumed, said to be simple tariff or uniform tariff.

$$\text{Cost per KWh} = \frac{\text{annual fixed cost} \times \text{annual operating cost}}{\text{total number of units supplied to the consumers per annum}}$$

Disadvantage:

- Cost/unit delivered is high, no discrimination between different types of consumers.\

c.Flat rate tariff:

- Different types of consumers are grouped [load factor and diversity factor] and are charged at different rates

Disadvantage:

- Separate meters are required for different types of supply. Difficulty in deriving load factor and diversity factor.

d.Step rate tariff:

- The cost of one KWh of energy is not fixed but goes down in steps as the energy consumption goes up.

Rs. 400/unit < 50 KWh
Rs. 4.50/unit > 50 KWh < 200 KWh
Rs. 3.00/unit > 200 KWh.

Advantage:

- It recognizes the fact of lower generation cost as higher energy consumption to improve load factor.

Disadvantage:

- By increasing the energy consumption next stage from previous stage, total energy cost is reduced.

e.Block rate tariff:

- When a given block of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively reduced rate, it is called a block rate tariff.

Advantage:

- The consumer gets an incentive for consuming more electrical energy, this increases the load factor and hence the generation cost is reduced.

Drawback:

- It lacks a measure the consumer's demand. It is most popular now-a-days among domestic, commercial and small scale industrial consumers.

f.Two part tariff or Hopkinson demand rate:

- When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the unit consumed, It is called a two –part tariff.
- The total charge is split into fixed and running charge.

Total energy charge e = Rs [b KW + c KWh].
It is most applicable to medium industrial consumers.

Drawbacks:

- Consumer has to pay the fixed charges irrespective of the fact. Always error in assessing the MD.

g.Maximum demand tariff:

- It is same like that of two part tariff except than in this case MD is actually measure by a MD indicator instead of merely assessing it on the basis of ratable value.

h.Power factor tariff:

- In ac system the size of plant is determined not only by KW capacity required, but also by PF.

KVA maximum demand tariff:

- ❖ Instead of KW, measuring will be on KVA and demand charge per KVA may be recovered in addition to charge proportional to the KWh consumption.

Sliding scale or Average PF tariff:

- ❖ An average PF of 0.8 lagging assumed as reference and a surcharge for each 0.01, below the PF value and discount will be provided if PF is.

KWh and KVARh tariff:

- ❖ Both active (KWh) and reactive (KVARh) units are separately charged, latter usage – fraction of KWh rate. A low PF means move KVARh component for each KWh.

a. Three part tariff:

- ❖ Only tariff which truly passes on the expenditure increased by the supply authority on to the consumer under all conditions of load.

Total cost e = a + b [KW or KVA] + c KWh

b. Off peak tariff:

- ❖ The consumers are encouraged to use electricity during off peak hours by giving a special discount, energy can be supplied without increasing an additional capital cost and should prove very profitable.
- ❖ Very advantageous for certain process such as water heating by thermal storage, pumping, refrigeration.

4. Compare the economics of following power plants.

(i)Nuclear and thermal power plants

No.	Nuclear power plant	Thermal power plants
1	More economical than thermal power plant at same capacity.	Not economical when compared with nuclear power plant of same capacity
2	The expenditure on fuel transport, handling and storage is less.	The expenditure on fuel transport, handling and storage is larger.
3	Less man power required.	More man power required.
4	Less space required.	More space required.
5	Cost of maintenance is high.	Cost of maintenance is low
6	Capital cost such as structural material piping and storage is less.	Capital cost such as structural material piping and storage is larger.
7	Operating cost is less.	Operating cost is high
8	Cost for waste disposal is less	Ash disposal cost is higher

(ii) (ii) Gas turbine and diesel power plant

No.	Gas turbine	Diesel power plants
1	Maintenance cost is less.	Maintenance cost is high.
2	Fuel cost is low because low grade fuel can be burnt	Fuel cost is high. High grade fuel can be burnt.
3	Initial cost is low	Initial cost is high.
4	Less space required	more space required

5	Poor part load efficiency	Good part load efficiency
6	It is economical for smaller output	It is not economical for smaller output
7	It is comparatively slow to respond to load variations	It is quick to respond to load variations

5. What are the fixed and operating costs of steam power plant? How are they accounted for fixing cost of electricity? (Dec 11)

- Power plant economics is important in controlling the total power costs to the consumer.
- Power should be supplied to the consumer at the lowest possible cost per kWh. The total cost of power generation is made up of fixed cost and operating cost.

EFFECT OF POWER PLANT TYPE ON COSTS

The cost of a power plant depends upon, when a new power plant is to set up or an existing plants to be replaced or plant to be extended. The cost analysis includes

1. Fixed Cost

It includes Initial cost of the plant, Rate of interest, Depreciation cost, Taxes, and Insurance.

2. Operational Cost

It includes Fuel cost, Operating labour cost, Maintenance cost, Supplies, Supervision, Operatingtaxes.

Initial Cost

The initial cost of a power station includes the following:

1. Land cost
2. Building cost
3. Equipment cost
4. Installation cost
5. Overhead charges, which will include the transportation cost, stores and storekeeping charges, interest during construction etc.

Operational Costs

The elements that make up the operating expenditure of a power plant include the following

(1) Cost of fuels.
(2) Labour cost.
(3) Cost of maintenance and repairs.
(4) Cost of stores (other than fuel).
(5) Supervision.
(6) Taxes.

Cost Of Fuels

- In a thermal station fuel is the heaviest item of operating cost. The selection of the fuel and the maximum economy in its use are, therefore, very important considerations in thermal plant design.
- It is desirable to achieve the highest thermal efficiency for the plant so that fuel charges are reduced.
- The cost of fuel includes not only its price at the site of purchase but its transportation and handling costs also.
- In the hydro plants the absence of fuel factor in cost is responsible for lowering the operating cost.

❖ Plant heat rate can be improved by the use of better quality of fuel or by employing better thermodynamic conditions in the plant design.

❖ The cost of fuel varies with the following:

(1) Unit price of the fuel.
(2) Amount of energy produced.
(3) Efficiency of the plant.

Labour Cost

❖ For plant operation labour cost is another item of operating cost. Maximum labour is needed in a thermal power plant using. Coal as a fuel.

❖ A hydraulic power plant or a diesel power plant of equal capacity requires a lesser number of persons.

❖ In case of automatic power station the cost of labour is reduced to a great extent.

❖ However labour cost cannot be completely eliminated even with fully automatic station, as they will still require some manpower for periodic inspection etc.

Cost of Maintenance and Repairs

❖ In order to avoid plant breakdowns maintenance is necessary. Maintenance includes periodic cleaning, greasing, adjustments and overhauling of equipment.

❖ The material used for maintenance is also charged under this head. Sometimes an arbitrary percentage is assumed as maintenance cost.

❖ A good plan of maintenance would keep the sets in dependable condition and avoid the necessity of too many stand-by plants.

❖ Repairs are necessitated when the plant breaks down or stops due to faults developing in the mechanism.

❖ The repairs may be minor, major or periodic overhauls and are charged to the depreciationfund of the equipment.

❖ This item of cost is higher for thermal plants than for hydro-plants due to complex nature of principal equipment and auxiliaries in the former.

Cost of Stores

❖ The items of consumable stores other than fuel include such articles as lubricating oil and greases, cotton waste, small tools, chemicals, paints and such other things.

❖ The incidence of this cost is also higher in thermal stations than in hydro-electric power stations.

Supervision

❖ In this head the salary of supervising staff is included. A good supervision is reflected in lesser breakdowns and extended plant life.

❖ The supervising staff includes the station superintendent, chief engineer, chemist, engineers, supervisors, stores incharges, purchase officer and other establishment.

❖ Again, thermal stations, particularly coal fed, have a greater incidence of this cost than the hydro-electricpower stations.

Taxes

The taxes under operating head includes the following:

(i) Income tax
(ii) Sales tax
(iii) Social security and employee's security etc.

The cost of power generation can be reduced by,

(i) Selecting equipment of longer life and proper capacities.

(ii) Running the power station at high load factor.

(iii) Increasing the efficiency of the power plant.

(iv)Carrying out proper maintenance of power plant equipment to avoid plant breakdowns.

(v) Keeping proper supervision as a good supervision is reflected in lesser breakdowns and extended plant life.

(vi) Using a plant of simple design that does not need highly skilled personnel.

- ❖ Power plant selection depends upon the fixed cost and operating cost.
- ❖ The fuel costs are relatively low and fixed cost and operation and maintenance charges are quite high in a case of a nuclear power plant.
- ❖ The fuel cost in quite high in a diesel power plant and for hydro power plant the fixed charges are high of the order of 70 to 80% of the cost of generation. Fuel is the heaviest items of operating cost in a steam power station.

A typical proportion of generating cost for a steam power station is as follows:

Fuel cost = 30 to 40%

Fixed charges for the plant = 50 to 60%

Operation and maintenance cost = 5 to 10%

- ❖ The power generating units should be run at about full load or the load at which they can givemaximum efficiency.
- ❖ It is necessary for a powerstation to maintain reliability and continuity of power supply at all times.
- ❖ In an electric power plant thecapital cost of the generating equipment's increases with an increase in efficiency.
- ❖ The benefit of suchincrease in the capital investment will be realized in lower fuel costs as the consumption of fuel decreaseswith an increase in cycle efficiency.

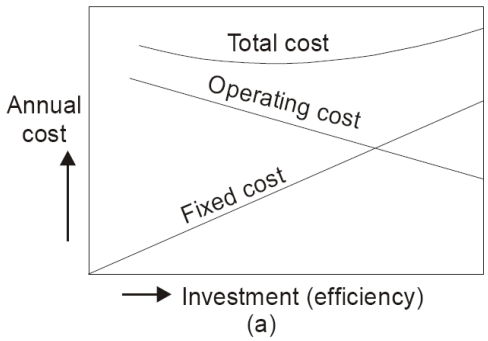


Fig. 3.1.shows the variation of fixed cost and operation cost with investment.

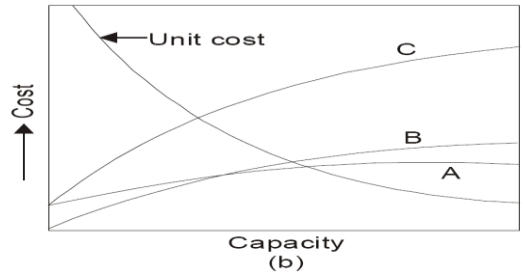


Fig.3.2. shows the variation of various costs of power plant versus its capacity.

6. Find the cost of generation per KW-hr from the following data:
Capacity of the plant – 120 MW
Capital cost- rs.1200 per KW installed
Interest and depreciation-10 % on capital
Fuel consumption-1.2 kg/kw-hr
Fuel cost-rs.40 tonne
Salaries, wages, repairs and maintenance – 600000/year
The maximum demand is 80 MW and load factor is 40%

Solution:

$$\text{Load factor} = \frac{\text{average load}}{\text{maximum load}}$$

$$0.4 = \frac{\text{average load}}{80}$$

Average load = 80x 0.4 =32 MW

Annual energy produced = 32x365x24 = 280320 MW-h

$$=280.3 \times 10^6 \text{kW-h}$$

Total capital cost = installed capacity xcapital cost per kW-h installed

$$=120 \times 10^3 \times 1200 = \text{Rs.}144 \times 10^6$$

Fuel consumption per year = fuel consumption xannual energy produced

$$=1.2 \times 280.3 \times 10^6$$

$$=336.364 \times 10^6 \text{ kg} = 336.36 \times 10^3 \text{tonne}$$

Fuel cost per year = Fuel consumption per year x cost of fuel

$$=336.36 \times 10^3 \times 40 = 13.45 \times 10^6$$

Fixed cost =annual interest and depreciation=$\text{Rs.}14.4 \times 10^6$

Annual running cost = fuel cost per year + cost of salaries, wages, repairs and maintenance

$$=\text{Rs.}13.45 \times 10^6 + \text{Rs.}60000$$

$$=\text{Rs.}14.05 \times 10^6$$

$$=\text{Rs.}14.4 \times 10^6 + 14.05 \times 10^6$$

$=28.45x10^6$

Generation cost per kw-h $= \frac{\text{Total cost per year}}{\text{annual energy produced}}$

$=(28.45x10^6)/(280.3x10^6)$

=Rs.0.1015/kW-h

7. A steam power station has an installed capacity of 120 MW and a maximum demand of 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annual expenses on salary bill of staff and other overhead charges excluding cost of coal are Rs.50 × 105. The power station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4 × 105. If the rate of interest and depreciation is 10% determine the cost of generating per kWh.

Solution.

Maximum demand = 100 MW

Load factor = 0.5

Average load = 100 × 0.5 = 50 MW = 50 × 1000 = 50,000 kW.

Energy produced per year = 50,000 × 8760 = 438 × 10^6 kWh.

Coal consumption = 438 × 106 × (0.4/1000) = 1752 × 10^6tonnes.

Annual Cost

(1) Cost of coal = 1752 × 102 × 80 = Rs. 14,016 × 10^2

(2) Salaries = Rs. 50 × 10^5

(3) Interest and depreciation = (10/100) × 4 × 10^5 = Rs. 4 × 10^4

Total cost = Rs. 14,016 × 10^3 + Rs. 50 × 105 + Rs. 4 × 10^4

= Rs. 19,056 × 10^3

Cost of generation per kWh $= \frac{(19{,}056 \times 10^3)}{438 \times 10^6} \times 100$

= 4.35 paise.Ans.

8. Write Short Notes on Air pollution in thermal power plant. Or Explain the analysis of pollution from thermal power plant. (Nov/dec 15) or Name the pollution control technologies adopted in thermal power plants and describe any one.(may/june 16)(Nov/Dec 2016)(May/June 17) (NOV/DEC 2017)

❖ The environmental pollution by thermal power plants using fossil fuels poses a serious healthhazard to modern civilization.

❖ Air pollution by thermal plants is a contributing factor in the cause ofvarious respiratory diseases and lung cancer and causes significant damage to the property in addition tocausing annoyance to the public.

❖ The thermal power plants burning conventional fuels (coal, oil or gas) contribute to air pollutionin a large measure.

❖ The combustible elements of the fuels are converted to gaseous products, and noncombustibleelements as ash.

❖ The common gaseous products of interest are sulphur dioxide, nitrogenoxide, carbon dioxide and carbon monoxide, and large quantities of particulate materials as fly ash,carbon particles, silica, alumina and iron oxide.

❖ The energy industries are one of the largest sources of environmental pollution.

❖ A 350 mWcoalfired station emits about 75 tons of SO2, 16 tons of nitrogen oxide, and 500 tons of ash per day if nosafeguards is adopted.

❖ All steam-generating plants also discharge nearly 60% of heat produced back tothe atmosphere irrespective of the fuel used.

❖ Due to large emissions from the thermal power plants, air pollution has become an internationalproblem.

❖ This problem is mainly faced by 11 countries in the world, which share 80% of the world'sfossil-fired generating capacity. Emissions from their power plants have grown to point where we andall of them now must think for controlling the pollution contributing to a common atmosphere.

❖ Many countries have unique air pollution problems. These are due to fuel characteristics,unfavorable topographical conditions, concentration of power plants in limited area and high populationdensities.

❖ The production capacities of 11 countries, which share 80% world-electric generation.

❖ Themajor pollutants given off by fossil fuel combustion are particulates, SO2 and other gases and it will be sufficient to discuss about these pollutants.

9. Write a Short Note on Water pollution in thermal power plant? (NOV/DEC 2017)

❖ Another serious problem is the water pollution caused by thermal power plants.

❖ The water pollutionis caused by discharging hot condenser water and water discharged into the river carrying the ash ofthe plant.

❖ The discharge of polluted water causes hydrological and biological effects on the surroundingecology.

❖ The biological study should determine the types of aquatic organisms in the area and theiradaptability to the environmental variations.

❖ Thermal pollution of water is very important for the fish cultivation, as their growth is verysusceptible to the temperature changes.

❖ Another important constituent in the discharge of cooling water is residual chlorine as chlorineor sodium hypochlorite is used to prevent fouling of the condensers.

❖ Another serious problem associated with the discharged water is the ash carried by the water.

❖ Theash gets spread over the large cultivated area along the path of the river and affects the agriculturalgrowth very much.

❖ This is because; the ash has high alkaline characteristics, which are injurious for thegrowth of many agricultural products.

❖ The ash destroys the fertility of the land forever. Such phenomenonwas badly experienced when the ash from Koradi thermal power station in Maharashtra was dischargedin the river.

❖ The wastewater from water demineralization plant contains large quantities ofchlorides of Ca, Mg, Na and K.

❖ This wastewater is channeled out to some river or to an ash pond alongthe fly ash. On the way to river or ash pond, these salts percolate in the nearby soil and make the groundwater salty.

❖ In the ash pond, the situation is worse as there is continuous accumulation of these salts andthe pond reaches a saturation level of these salts.

❖ The process of salt saturation in the pond is furtheraccelerated by solar evaporation of the water.

❖ The wells on the area covering a few kilometers from theponds become salty and polluted water from these wells becomes harmful for human consumption aswell as for irrigation purposes.

❖ Discharging these salts with the wastewater aggravates the pollutionproblem but also loses them, even though; their recovery is simple and economical

❖ The wastewater can be treated first with lime, to precipitate magnesium hydroxide and then withsoda ash to get precipitated calcium carbonate and the resulting sodium chloride solution can be reusedfar regeneration of softeners. The above-mentioned reactions are listed below.

$$MgCl2 + Ca(OH)2 = Mg(OH)2 \downarrow + CaCl2$$
$$CaCl2 + Na2\,CO3 = CaCO3 \downarrow + 2\,NaCl.$$

10. Write short notes on Environmental concerns in diesel power plants.

❖ With the emergence of liquid fuel based power stations in India, the question of environmentpollution has become a matter of raging debate.

❖ The coal based thermal power stations, in its earlierstages of inception, were far more polluting? It was because of the combination of sulphur-based pollutants,nitrogen based gaseous matter and also particulate matter with very high ash content being releasedin the atmosphere.

❖ Globally, environmental regulatory authorities are increasingly concerned with NO*x*and So*x*emissions and are liable to consider introducing stringent regulatory standards in the future.

❖ While thelevels of SO*x*emissions is the function of sulphur content inhered in the fuel being used for combustion?

❖ NO*x*is created by the chemical activity between atmospheric oxygen and nitrogen during combustion.The level of NO*x*depends on the combustion conditions.

❖ Optimal combustion in a diesel engine depends upon the achievement of the right balance ofequation between compression/combustion pressure, compression ratio, air-to-fuel ratio and mean effectivepressure.

❖ The toughest of the emission standards currently being considered by various nationaland international agencies, calls for limitation of NO*x*emissions to 600 ppm(15% O2) for generator setsoperating on ocean bound vessels.

❖ The shore-based power stations shall demand for further lower limitsdue to proximity to the human inhabitation.

❖ Burning heavy fuel in diesel engine is convenient mainly due to economics of residual fuelcombustion for power generation.

❖ Diesel engine designers' world over will increasingly come underpressure to introduce superior combustion features for producing lower levels of SO*x*and NO*x*.

❖ The exhaust gas composition of emissions or pollutants given above is for using furnace oil ofdifferent grades and varying sulphur contents.

❖ The exhaust gas of medium speed engines comprises ofa host of constituents. In the case of combusting heavy fuel like furnace oil, these emanate either fromcombustion air and fuel used, or they are reaction products, which get formed during the combustionprocess. Only some of these are considered to be pollutants for the atmosphere:

<u>Carbon dioxide (CO2)</u>:

❖ CO2 actually is not noxious as a product of combustion of all fossilfuels.

❖ It is now considered to be one of the main causes of the greenhouse effect.

❖ A reduction of CO2emission can only be achieved by improving the engine efficiency or by using fuels containing lowerconcentration of carbon such as natural gas.

Sulphur oxides (SO*x*):

❖ Sulphur oxides are formed due to the combustion of sulphur contained inthe fuel.

❖ They are one of the primary causes of acid rain. The sulphur oxide emission is primarilyinfluenced by the amount of sulphur contained in the fuel used.

❖ Much less influence can be taken by thefuel consumption of engine. The major part (> 95%) of sulphur oxides contained in the exhaust gas ofthe diesel engines is SO2.

Nitrogen oxides NO*x*(NO, NO2, N2O):

❖ Nitrogen oxides which are generally referred to as NO*x*inthe case of internal combustion engines comprise nitrogen monoxide-NO (colourless, water insolublegas), nitrogen dioxide-NO2 (reddish brown gas, highly toxic) and dinitrogen monoxide-N2O (laughinggas, colourless gas previously used as a narcotic).

❖ Nitrogen oxides, together with the sulphur oxides are themain causes of acid rain.

❖ They also contribute essentially to ozone formation in the air and ground level.

❖ The high temperatures and pressures produced in the combustion space of an IC engine stimulatethe nitrogen content in the air and also in the grades used (such as heavy fuel oil) to react with oxygen inthe combustion air. In this reaction mechanism, the formation of nitrogen oxides proportionally increaseswith the temperature rise.

❖ This behavior unfortunately combats the efforts of improving onengine efficiency because conversion of energy at the highest possible temperature level is to be aimedfor to reach the optimal efficiencies of combustion processes.

❖ The NO*x*formation during combustion in the diesel engine is predominantly NO and which isconverted to a minor extent to NO2 by oxidation either in the combustion space or in the exhaust gassystems downstream (exhaust gas piping, exhaust gas turbo charger etc.).

❖ In general, exhaust gas leavingthe engine is 95% NO and approximately 5% NO2.

❖ To simulate the process of NO oxidation, to formNO2 in the atmosphere, practically, all the legislation stipulate that in the calculation of NOx mass flowemitted, the entire NO*x*must be taken as NO2.

❖ The N2O concentration in the exhaust gas of mediumspeed diesel engines, burning heavy fuel is limited to a few ppm. Therefore, it can be neglected from theviewpoint of environmental protection.

Carbon Monoxide (CO):

❖ It is a colourless, highly noxious gas which forms where the combustionof fuels containing carbon proceeds under(possibly local) air starvation.

❖ In modern DG sets,optimisation of air/fuel mixture formation and use of constant pressure type turbo charging, successfullyreduces the CO content of exhaust gases even with the poorest qualities of fuel grades.

❖ This type ofengine design meets even the stringent standards set by such environmental agencies like TA-Luft ofGermany.

Non combusted Hydro carbons(HC):

❖ Hydro carbons contained in the exhaust gas consistsof a multitude of various organic compounds.

❖ However, the HC contents of exhaust gases for modern4-stroke diesel engines burning heavy fuel are very low and are not a matter of environmental debate.

Soot, Dust:

❖ Solids contain in exhaust gases of diesel engines burning heavy fuel not only consistof soot (carbon) resulting due to incomplete combustion of the fuel but also due to dust and ash particlesfrom the fuel and the lube oil, the quality of the combustion air and from the abrasion products.

❖ Eventhough, these constitutes the major source of visible dark coloration, of exhaust gases, soot particlesonly account for a relatively low percentage of total dust concentration.

❖ Based on the ash content of thefuel and the lube, the soot quantity also varies as shown in the table below.

Fuel	**Gas Oil**	**Heavy Fuel Oil**
Ash content — Fuel%	0.01	0.10
Ash content — Lube%	1.50	4.00
Soot (Carbon) mg/m3	15.00	15.00
Fuel ash mg/m3	4.00	40.00
Lube oil ash mg/m3	3.00	8.00

❖ Overall analysis of environmental laws will take us into two pronged environmental considerations.

I. Long term consideration on implementation of actual system emission limits. This should takeinto account existing technology, cost competitiveness, consideration to burn only low grade, tertiaryfuels, demand technology life-cycle, nature of project and plant gestation and country objectives.

II. Short term aspects mainly centred on maintaining desired ambient air qualities. This willbring us to the debate emission levels. The ground level dispersion of emission components are easilymet far below existing standards by the modern 4-stroke diesel engines while burning heavy fuel.

❖ In view of the above, adequate chimney/stack heights for guiding the exhaust gases away fromthe ground level can easily ensure low dispersions at ground level after emission at relevant designedchimney heights based on sulphur contents in the fuel.

11. Write short notes on Environmental concerns in nuclear power plant .

❖ Besides thermal pollution, which it shares with almost all types of power plants, nuclear power'seffects on the environment stem mainly from

(1) the nuclear fuel cycle,

(2) low-level dose radiations from nuclear-power plant effluents, and (3) low and high-level doseradiations from wastes.

1. The fuel cycle:

❖ Most nuclear power plants in operation or under construction in the world today are using, and will continue to use for the near future, ordinary (light) water cooled and moderated reactors: the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR).

❖ A small number use the heavy water cooled and moderated reactor (PHWR).

❖ The expectations are that the fast-breeder reactor power plant and perhaps an improved version of the gas-cooled reactor power plant will come on line in increasing numbers in the twenty-first century.

❖ Almost all-current water reactors use slightly enriched uranium dioxide, UO2, fuel.

❖ The fuel has to go through a cycle that includes prereactor preparation, called the front end in-reactor use, and post reactor management, called the back end.

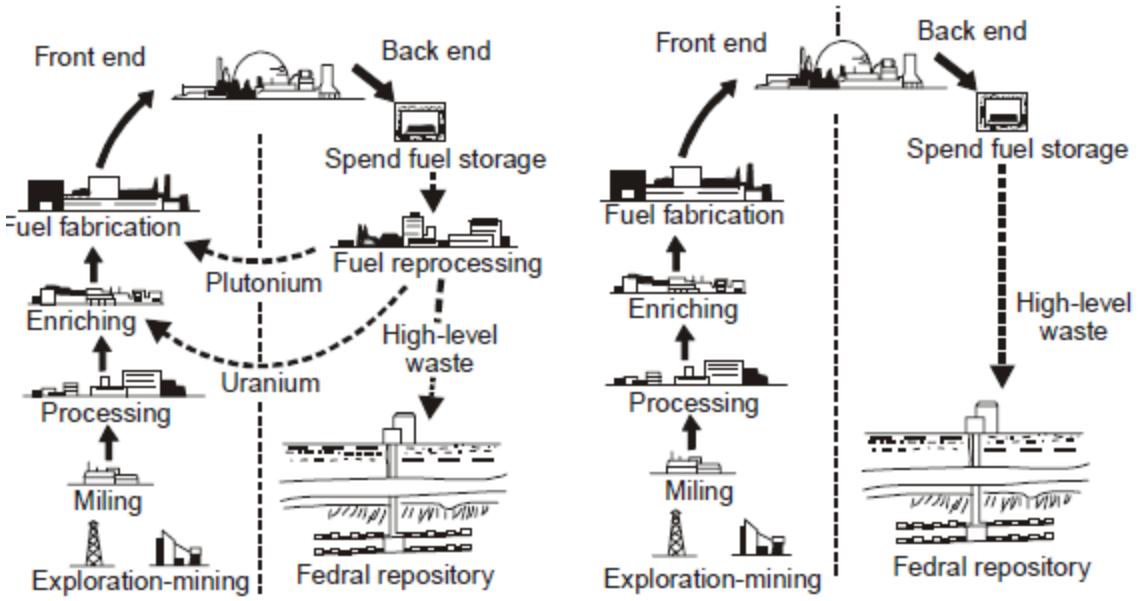


Fig. 11.1. A typical nuclear fuel cycle (*a*) with reprocessing and (*b*) without reprocessing.

The different process are briefly explained below:

- Mining of the uranium ore.
- Milling and refining of the ore to produce uranium concentrates, U3O8.
- Processing to produce of uranium hexafluoride, UF6, from the uranium concen-trates. Thisprovides feed for isotopic (U235) enrichment.
- Isotopic enrichment of uranium hexafluoride to reach reactor enrichment require-ments. Thisis done invariably now by the gaseous diffusion process.
- Fabrication of the reactor fuel elements. This includes conversion of uranium hexafluoride touranium dioxide UO2, pelletizing, encapsulating in rods, and assembling the fuel rods intosubassemblies.
- Power generation in the reactor, resulting in irradiated or spent fuel.
- Short-term storage of the spent fuel.
- Reprocessing of the irradiated fuel and conversion of the residual uranium to uraniumhexafluoride, UF6 (for recycling through the gaseous diffusion plant for reenrichment) and/orextraction of Pu239 (converted from U238) for recycling to the fuel-fabrication plant.Reprocessing can reuse up to 96 percent of the original material in the irradiated fuel with 4percent actually becoming waste.
- Waste management, which includes long-term storage of high-level wastes.
- Step 8, reprocessing, may be bypassed, which results in disposal of both reusable fuel and wastes.This is the current (1982) U.S. Department of Energy process for dealing with irradiated fuel. The fuelassemblies are stored for at least 10 years and then buried. This is the so-called throw-away fuel cycle.

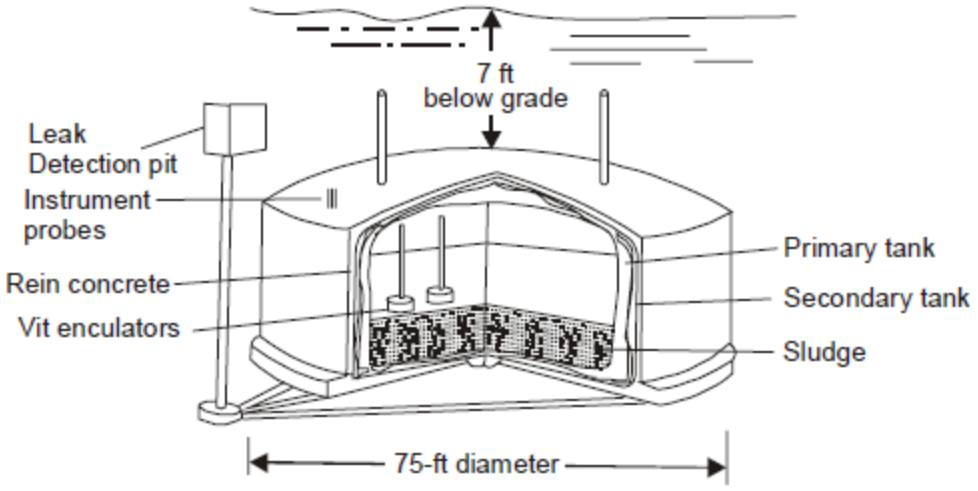


Fig. 11.2. A typical low-level liquid-waste storage tank with double-walled containment.

WASTES

The wastes associated with nuclear power can be summarized as:

1.Gaseous effluents.

- Under normal operation, these are released slowly from the power plantsinto the biosphere and become diluted and dispersed harmlessly.

2.Uranium mine and mill tailings.

- Tailings are residues from uranium mining and millingoperations.
- They contain low concentrations of naturally occurring radio-active materials. They aregenerated in large volumes and are stored at the mine or mill sites.

3. Low-level wastes (LLW).

- These are classified as wastes that contain less than 10 nCi(nanocuries) per gram of transuranium contaminants and that have low but potentially hazardous concentrationsof radioactive materials.
- They are generated in almost all activities (power generation, medical,industrial, etc.) that involve radioactive materials, require little or no shielding, and are usuallydisposed of in liquid form by shallow land burial

4.High-level wastes (HLW).

- These are generated in the reprocessing of spent fuel.
- They containessentially all the fission products and most of the transuranium elements not separated duringreprocessing. Such wastes are to be disposed of carefully.

4. **Spent fuel.**

- This is unreprocessed spent fuel that is removed from the reactor core after reachingits end-of-life core service.
- It is usually removed intact in its fuel element structural form and thenstored for 3 to 4 months under water on the plant site to give time for the most intense radioactiveisotopes (which are the ones with shortest half-lives) to decay before shipment for reprocessing ordisposal.
- Lack of a reprocessing capacity or a disposal policy has resulted in longer on-site storage,however.
- If the spent fuel is to be disposed of in a throwaway system (without reprocessing), it is treatedas high-level waste.

22. Briefly explain the Radiations from nuclear-power plant effluents?

❖ Radiations from nuclear-power plant effluents are low-dose-level types of radiations. The effluentsare mainly gases and liquids.

❖ Mainly the effects of these radiations on the populations living nearthe plants prompt environmental concerns about nuclear power plants.

❖ Sources of effluents vary withthe type of reactor.In both pressurized-water reactors (PWR) and boiling-water reactors (BWR),

Two importantsources of effluents are

(1) The condenser steam-jet air ejectors and

(2) The turbine gland-seal system.

❖ The ejector uses high-pressure steam in a series of nozzles to create a vacuum, higher than that inthe condenser, and thus draws air and other non-condensable gases from it.

❖ The mixture of steam andgases is collected, the steam portion condenses, and the gases are vented to the atmosphere.

❖ In the glandseal, high-pressure steam is used to seal the turbine bearings by passing through a labyrinth from theoutside in so that no turbine steam leaks out and, in the case of low-pressure turbines, no air leaks in.

❖ Theescaping gland-seal steam is also collected and removed. In the BWR, the effluents come directly fromthe primary system.

❖ In the PWR, they come from the secondary system, so there is less likelihood ofradio-active material being exhausted from a PWR than a BWR from these sources.

❖ The primary-coolant radioactivity comes about mainly from fuel fission products that find theirway into the coolant through the few small cracks that inevitably develop in the very thin cladding ofsome fuel elements.

❖ Such activity is readily detectable. However, to avoid frequent costly shutdownsand repairs, the system is designed to operate as long as the number of affected fuel elements does notexceed a tolerable limit, usually 0.25 to 1 percent of the total.

❖ Also, some particulate matter finds its wayinto the coolant as a result of corrosion and wear (erosion) of the materials of the primary system components.

❖ These become radioactive in the rich neutron environment of the reactor core. Corrosionoccurs because the radiolytic decomposition of the water passing through the core results in free O2 andfree H and OH radicals as well as some H2O2. These lower the pH of the coolant and promote corrosion.

❖ Finally, radioactivity in the primary coolant may be caused by so-called *tramp uranium*.

❖ This is uraniumor uranium dioxide dust that clings to the outside of the fuel elements and is insufficiently cleaned offduring fabrication.

❖ It will, of course, undergo fission, and its fission products readily enter the coolant.Improved processing and quality control are minimizing the problem of tramp uranium.

12. Explain the pollution control methods for various power plants? (NOV/DEC 2017)

❖ The following methods for developing the power generating capacity without pollution to the atmosphere.

❖ 1. F.P. Rogers has suggested that it would be safer to set the nuclear power plants underground. This definitely preserves the environment. There would be lot of difficulties in excavation, concreting, roof lining, structural supporting, lowering the reactor equipments and many others.

❖ But even then it is suggested that locating the power plant underground would be profitable in the long run.

❖ The tidal power must be developed in the coining years that is free from pollution.

❖ The thermal discharges to the environment are common from fossil and nuclear-fueled power stations.

❖ Significant quantities of particulates and gases from fossil-fueled system, small quantities of radioactive gases from nuclear, have an impact upon an environment.

❖ Offshore sitting of power plants mitigates these problems of pollution. Offshore sitting of power stations also isolates the plants from earthquakes and provides the thermal enhancement of the water to increase recreational and commercial values.

❖ No doubt, offshore location requires new design consideration and floating platforms in the sea increasing the capital cost of the plant.

❖ It was proposed that the thermal pollution of the atmosphere and the generation cost of the plant could be reduced by using the low-grade energy exhausted by the steam.

❖ The ideal use for enormous quantity of residual energy from steam power plants requires large demand with unity power factor.

❖ Particularly in U.S.A., many uses of energy are available in winter, but not in summer therefore finding large-scale valuable uses of thermal energy is the key for developing beneficial uses.

❖ It is estimated that the total energy used in U.S.A. for air-conditioning is equivalent to the total energy used for heating the offices and residences.

❖ The low-grade energy Exhaust by the thermal plants is not readily usable for air-conditioning purposes.

❖ It is possible to use this energy by stopping the expansion of steam at a temperature of 95°C to 100°C and use of this energy can be made to drive an absorption refrigeration system such as lithium bromide water system.

❖ This will be a definite positive answer to reduce the thermal pollution of environment otherwise caused by burning extra fuel to run the absorption refrigeration system in summer or to run the heating systems in winter.

❖ As for open field irrigation, soil heating with warm water and better cultivation of the fishes in slightly warm water.

❖ In short, a combination of uses could consume all heat from a large thermal power station, making conventional cooling unnecessary and reduce the generating cost with minimum thermal pollution of the atmosphere.

❖ . Use the sun energy for the production of power that is absolutely free from air-pollution.

13. Write Short Notes on Nuclear Waste and Its Disposal.or Write a short notes on nuclear waste disposal. (Nov/dec 15)(Nov/Dec 16) (May/June 17) (NOV/DEC 2017)

Nuclear waste:

Nuclear power is the only large-scale energy-producing technology which takes full responsibility for all its wastes and fully costs this into the product.

- The amount of radioactive wastes is very small relative to wastes produced by fossil fuel electricity generation.
- Used nuclear fuel may be treated as a resource or simply as a waste.
- Nuclear wastes are neither particularly hazardous nor hard to manage relative to other toxic industrial wastes.
- Safe methods for the final disposal of high-level radioactive waste are technically proven; the international consensus is thatthis should be geological disposal.
- All parts of the nuclear fuel cycle produce some radioactive waste (radwaste) and the relatively modest cost of managing and disposing of this is part of the electricity cost, *i.e.* it is internalised and paid for by the electricity consumers.

Types of radioactive wastes

Exempt waste & very low level waste

- Exempt waste and very low level waste (VLLW) contains radioactive materials at a level which is not considered harmful to people or the surrounding environment.
- It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping *etc*) produced during rehabilitation or dismantling operations on nuclear industrial sites.
- Other industries, such as food processing, chemical, steel *etc* also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes.

Low-level waste

- Low-level waste (LLW) is generated from hospitals and industry, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters*etc*, which contain small amounts of mostly short-lived radioactivity.
- It does not require shielding during handling and transport and is suitable for shallow land burial.
- To reduce its volume, it is often compacted or incinerated before disposal. It comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste.

Intermediate-level waste

- Intermediate-level waste (ILW) contains higher amounts of radioactivity and some requires shielding.
- It typically comprises resins, chemical sludges and metal fuel cladding, as well as contaminated materials from reactor decommissioning.
- Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. It makes up some 7% of the volume and has 4% of the radioactivity of all radwaste.
- By definition, its radioactive decay generates heat of less than about 2 kW/m^3 so does not require heating to be taken into account in design of storage or disposal facilities.

High-level waste

❖ High-level waste (HLW) arises from the 'burning' of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core.

❖ It is highly radioactive and hot due to decay heat, so requires cooling and shielding.

❖ It has thermal power above about 2 kW/m^3 and can be considered as the 'ash' from 'burning' uranium. HLW accounts for over 95% of the total radioactivity produced in the process of electricity generation.

❖ There are two distinct kinds of HLW:

- Used fuel itself.
- Separated waste from reprocessing the used fuel (as described in section on Managing HLW from used fuel below).

Mining and milling

❖ Traditional uranium mining generates fine sandy tailings, which contain virtually all the naturally occurring radioactive elements naturally found in uranium ore.

❖ These are collected in engineered tailings dams and finally covered with a layer of clay and rock to inhibit the leakage of radon gas and ensure long-term stability.

❖ In the short term, the tailings material is often covered with water.

❖ After a few months, the tailings material contains about 75% of the radioactivity of the original ore. Strictly speaking these are not classified as radioactive wastes.

Conversion, enrichment, fuel fabrication

❖ Uranium oxide concentrate from mining, essentially 'yellowcake' (U3O8), is not significantly radioactive – barely more so than the granite used in buildings.

❖ It is refined then converted to uranium hexafluoride gas (UF6). As a gas, it undergoes enrichment to increase the U-235 content from 0.7% to about 3.5%.

❖ It is then turned into a hard ceramic oxide (UO2) for assembly as reactor fuel elements.

Recycling used fuel

❖ Any used fuel will still contain some of the original U-235 as well as various plutonium isotopes which have been formed inside the reactor core, and the U-238[c].

❖ In total these account for some 96% of the original uranium and over half of the original energy content (ignoring U-238).

❖ Reprocessing, undertaken in Europe and Russia, separates this uranium and plutonium from the wastes so that they can be recycled for re-use in a nuclear reactor .

❖ Major commercial reprocessing plants operate in France, UK, and Russia with a capacity of some 5000 tonnes per year and cumulative civilian experience of 80,000 tonnes over 50 years.

❖ A new reprocessing plant with an 800 t/yr capacity at Rokkasho in Japan is undergoing commissioning. There are several proposed developments of reprocessing

❖ This however cannot be simply put into MOX fuel and recycled in conventional reactors; it requires fast neutron reactors which are as yet few and far between. On the other hand, it would make disposal of high-level wastes easier.

Storage and disposal of used fuel and other HLW

❖ Some storage of fuel assemblies which have been cooling in ponds for at least five years is in dry casks, or vaults with air circulation inside concrete shielding.

❖ For storage, each is enclosed in a ventilated storage module made of concrete and steel.

❖ These are commonly standing on the surface, about 6m high, cooled by air convection, or they may be below grade, with just the tops showing.

❖ The modules are robust and provide full shielding. Each cask has up to 45 kW heatload.

❖ For disposal, to ensure that no significant environmental releases occur over tens of thousands of years, 'multiple barrier' geological disposal is planned.

❖ This immobilises the radioactive elements in HLW and some ILW and isolates them from the biosphere.

The main barriers are:

- ❖ Immobilise waste in an insoluble matrix such as borosilicate glass or synthetic rock (fuel pellets are already a very stable ceramic: UO2).
- ❖ Seal it inside a corrosion-resistant container, such as stainless steel.
- ❖ Locate it deep underground in a stable rock structure.
- ❖ Surround containers with an impermeable backfill such as bentonite clay if the repository is wet.

Waste management for used fuel and HLW from nuclear power reactors

Country	Policy	Policy
India	Reprocessing	• Research on deep geological disposal for HLW
Belgium	Reprocessing	• Central waste storage at Dessel • Underground laboratory established 1984 at Mol • Construction of repository to begin about 2035

Canada	Direct disposal	• Nuclear Waste Management Organisation set up 2002 • Deep geological repository confirmed as policy, retrievable • Repository site search from 2009, planned for use 2025
China	Reprocessing	• Central used fuel storage at LanZhou • Repository site selection to be completed by 2020 • Underground research laboratory from 2020, disposal from 2050
Germany	Reprocessing but moving to direct disposal	• Repository planning started 1973 • Used fuel storage at Ahaus and Gorleben salt dome • Geological repository may be operational at Gorleben after 2025
Japan	Reprocessing	• Underground laboratory at Mizunami in granite since 1996 • • Used fuel and HLW storage facility at Rokkasho since 1995 • Used fuel storage under construction at Mutsu, start up 2013 • NUMO set up 2000, site selection for deep geological repository under way to 2025, operation from 2035, retrievable
United Kingdom	Reprocessing	• Low-level waste repository in operation since 1959

		• HLW from reprocessing is vitrified and stored at Sellafield

Wastes from decommissioning nuclear plants

- In the case of nuclear reactors, about 99% of the radioactivity is associated with the fuel.
- Apart from any surface contamination of plant, the remaining radioactivity comes from 'activation products' such as steel components which have long been exposed to neutron irradiation.
- Their atoms are changed into different isotopes such as iron-55, cobalt-60, nickel-63 and carbon-14.
- The first two are highly radioactive, emitting gamma rays, but with correspondingly short half-lives so that after 50 years from final shutdown their hazard is much diminished. Some caesium-137 may also be in decommissioning wastes.
- Some scrap material from decommissioning may be recycled, but for uses outside the industry very low clearance levels are applied, so most is buried.
- Generally, short-lived intermediate-level wastes (mainly from decommissioning reactors) are buried, while long-lived intermediate-level wastes (from fuel reprocessing) will be disposed of deep underground. Low-level wastes are disposed of in shallow burial sites.

14. Define demand factor, load factor, diversity factor, reserve factor. (May/June17)

Load factor

- Load factor is the ratio of average demand to the maximum demand during a certain period of time and is applicable to both generating equipment and receiving equipment.

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Maximum demand}}$$

Diversity factor.

- Diversity factor is defined as the state of being dissimilar to oneanother. It is defined as the ratio of sum of the maximum demands of individual consuming units in a group during a specified period to the maximum demand of the whole group during the same period.

$$\text{Diversity factor} = \frac{\text{Sum of individual demands of diffrernt units in a group}}{\text{Maximum demand of the entire group}}$$

- The value of diversity factor is always greater than one. If the diversity factor is higher, the cost per unit of generation will be lesser.

Demand factor:

It is the ratio of actual maximum demand of system to the total connected demand of the system.

$$\textbf{Demand factor} = \frac{\text{Actual maximum demand}}{\text{Total connected demand}}$$

Reserve factor

$$\textbf{Reserve factor} = \frac{\text{Load factor}}{\text{Capacity factor}}$$

SOLVED PROBLEMS:

1. Determine the thermal efficiency of a steam power plant and its coal bill per annumusing the following data.
Maximum demand = 24000 kW
Load factor = 40%
Boiler efficiency = 90%
Turbine efficiency = 92%
Coal consumption = 0.87 kg/Unit
Price of coal = Rs. 280 per tone (APR/MAY 2018)

Solution.
η = Thermal efficiency
= Boiler efficiency × Turbing efficiency
= 0.9 × 0.92 = 0.83
Load factor = Average Load/Maximum Demand
Average Load = 0.4 × 24000 = 9600 kW
E = Energy generated in a year = 9600 × 8760 = 841 × 105 kWh
Cost of coal per year = (E × 0.87 × 280)/1000
= (841 × 105 × 0.87 × 280)/1000
= Rs. 205 × 105. Ans.

2. The maximum (peak) load on a thermal power plant of 60 mW capacity is 50 MW atan annual load factor of 50%. The loads having maximum demands of 25 MW, 20 MW, 8 MW and, 5MWare connected to the power station.
Determine: (a) Average load on power station (b) Energy generated per year
(c) Demand factor(d) Diversity factor.
Solution.
(*a*) Load factor = Average load/Maximum demand
Average load = 0.5 × 50 = 25 mW
(*b*) E = Energy generated per year
= Average load × 8760
= 219 × 106 kWh.
(*c*) Demand factor = Maximum demand/Connected load

= 50/(25 + 20 + 8 + 5) = 0.86

(*d*) Diversity factor = $\frac{M1}{M2}$

Where Ml = Sum of individual maximum demands = 25 + 20 + 8 + 5 = 58 MW

M2 = Simultaneous maximum demand = 50 mW

Diversity factor = $\frac{58}{50}$

= **1.16. Ans.**

3. In a steam power plant the capital cost of power generation equipment is Rs. 25 ×105. The useful life of the plant is 30 years and salvage value of the plant to Rs. 1 × 105. Determine bysinking fund method the amount to be saved annually for replacement if the rate of annual compoundinterest is 6%.

Solution.

P = Capital cost = Rs. 20×10^5

S = Salvage value = Rs. 1×10^5

n = Useful life = 30 years

r = Compound interest

A = Amount to be saved per year for replacement

$$A = \frac{(P - s)r}{(1 + r)^n} = \frac{(20 \times 10^5 - 1 \times 10^5)0.06}{\{(1 + 0.06)^{30} - 1\}}$$

$$= \mathbf{Rs.\,24{,}000//}$$

4. A hydro power plant is to be used as peak load plant at an annual load factor of 30%. The electrical energy obtained during the year is 750 × 105 kWh. Determine the maximum demand.If the plant capacity factor is 24% find reserve capacity of the plant.

Solution.

E = Energy generated = 750 × 105 kWh

Average load = $((750 * 105))/8760$ = 8560 kW

where 8760 is the number of hours in year.

Load factor = 30%

M = Maximum demand

Load factor = Average load/Maximum demand

M = $\frac{85{,}600}{0.3}$

= 28.530 kW

C = Capacity of plant

$$\text{Capacity factor} = \frac{E}{(C \times 8760)}$$

$$0.24 = \frac{750 \times 10^5}{(C \times 8760)}$$

C = 35,667 kv
Reserve capacity = C – M = 35,667 – 28,530
= 7137 kW. Ans.

5. A diesel power station has fuel consumption 0.2 kg per kWh. If the calorific value ofthe oil is 11,000 kcal per kg determine the overall efficiency of the power station.
Solution.
For 1 kWh output
Heat input = 11,000 × 0.2 = 2200 kcal.
Now 1 kWh = 862 kcal.

$$\text{over all efficiency} = \frac{\text{out put}}{\text{input}} = \frac{866}{2200} = 39.2\%$$

6. A steam power station has an installed capacity of 120 MW and a maximum demandof 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annualexpenses on salary bill of staff and other overhead charges excluding cost of coal are Rs.50 × 105. Thepower station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4 × 105. If therate of interest and depreciation is 10% determine the cost of generating per kWh.

Solution.
Maximum demand = 100 mW
Load factor = 0.5
Average load = 100 × 0.5 = 50 MW = 50 × 1000 = 50,000 kW.

Energy produced per year = 50,000 × 8760 = 438 × 106 kWh.

Coal consumption = 438 × 106 × (0.4/1000) = 1752 × 106 tonnes.

Annual Cost
(1) Cost of coal = 1752 × 102 × 80 = Rs. 14,016 × 102
(2) Salaries = Rs. 50 × 105
(3) Interest and depreciation = (10/100) × 4 × 105 = Rs. 4 × 104

Total cost = Rs. 14,016 × 103 + Rs. 50 × 105 + Rs. 4 × 104
= Rs. 19,056 × 103

Cost of generation per KWh $= \left\{\frac{19.056\times10^3}{438\times10^6}\right\} \times 100$
= 4.35 paise. Ans.

7. Any undertaking consumes 6 × 106 kWh per year and its maximum demand is 2000kW. It is offered two tariffs.

(a) Rs. 80 per kW of maximum demand plus 3 paise per kWh.
(b) A flat rate of 6 paise per kWh.
Calculate the annual cost of energy.
Solution.

(a) According to first tariff the cost of energy

$$= 2000 \times 80 + \left(\frac{3}{100}\right) \times 6 \times 10^6$$

$$= 160{,}000 + 180{,}000 = \text{Rs: } 340{,}000$$

(b) Cost of energy according to flat rate;

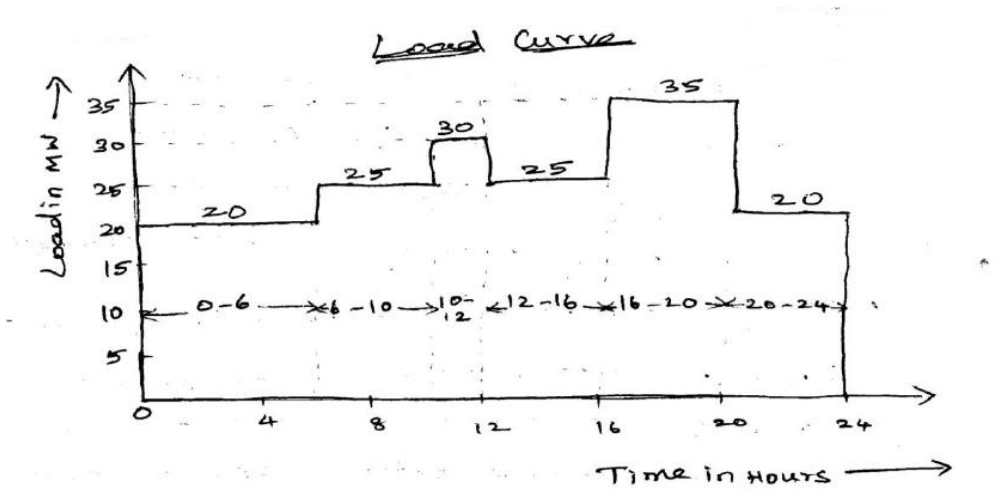
$$= \left(\frac{6}{100}\right) \times 6 \times 10^6 = \text{Rs: } 360{,}000$$

Extra problems

1.A generating station has the following daily load cycle;

Time(Hrs)	0-6	6-10	10-12	12-16	16-20	20-24
Load(MW)	20	25	30	25	35	20

Draw the load curve and calculate
1. Maximum demand,
2. Units generated/day
3. Average load.
4. Load factor nov/Dec-2013



Solution:

1. Maximum demand $= 35\text{MW}$

2. units generated per day = Area under load curve in kwhr

$= (6 \times 20) + (4 \times 25) + (2 \times 30) + (4 \times 25) + (4 \times 35) + (4 \times 20)$

$= 600 \times 10^3\ \text{KWhr} = 600\text{MWhr}$

3. Average load $= \dfrac{\text{units generated per day}}{\text{Hours in a day}}$

$$\text{Average load} = \frac{600 \times 10^3}{24} = 25000\text{KW}$$

$$\text{Average load} = 25\text{MW}$$

$$4.\ \text{load factor} = \frac{\text{Average load}}{\text{Maximum demand}} = \frac{25}{35} = 0.7143 = 71.43\%$$

Result:

1. Maximum demand = 35MW
2. units generated per day = 600MWhr
3. Average load = 25MW
4. load factor = 0.7143 = 71.43%

2.A power station has to meet the following demand:

Group A: A-200 KW between 8 Am to 6 Pm

Group B: A-100 KW between 6 Am to 10 Am

Group C: A-50 KW between 6 Am to 10 Pm

Group D: A-100 KW between 10 Am to 6 Pm and between 6 PM to 6 Am.

Plot the daily load curve and Determine:

1. Diversity factor.

2. units generated per day,

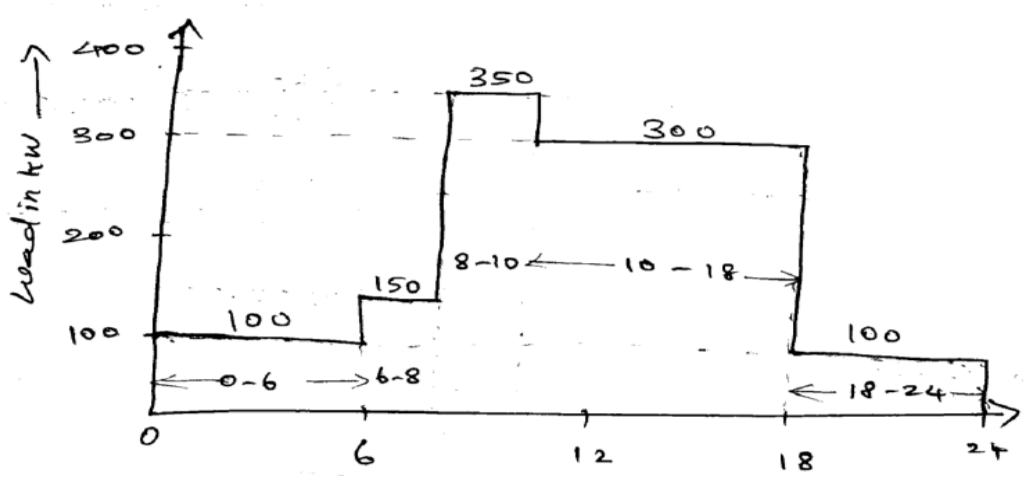
3. Load factor. (Apr/May – 2008)

Solution:

To Tabulate maximum load

Time (hours) / Group	0-6	6-8	8-10	10-18	18-24
A	—	—	200	200	—
B	—	100	100	—	—
C	—	50	50	—	—
D	100	—	—	100	100
Total load on Power station	100	150	350	300	100

Load curve:



$$\text{Maximum demand} = 350\text{kw}$$

$$1.\ \text{Diversity factor} = \frac{\text{Sum of all individual maximum demand}}{\text{Maximum demand on station}}$$

$$= \frac{200 + 100 + 50 + 100}{350} = 1.286$$

2. Units generated per day = Area under the load curve

$$= (6 \times 100) + (2 \times 150) + (2 \times 350) + (8 \times 300) + (6 \times 100)$$
$$= 4600\text{Kwhr}$$

$$\textbf{3.}\ \text{Load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$\text{Average load} = \frac{\text{Units generated per day}}{\text{Hours in a day}}$$

$$= \frac{4600}{24} = 191.667\text{KW}$$

$$\text{Load factor} = \frac{191.667}{350} = 0.5476 = 54.76\%$$

Result:

1. Diversity factor = 1.286

2. Units generated per day = 4600Kwhr

$$3.\text{Loadfactor} = 0.5476 = 54.76\%$$

3. The maximum demand on a power station is 100MW.if the annual load factor is 40%., calculate the total energy generated in a year NOV/DEC-2008

Solution

Maximum Demand $= 100\text{Mw}$

Annual load factor $= 40\% = 0.4$

$$\text{load factor} = \frac{\text{Energy generated per annum}}{\text{Maximum demand} \times 365 \times 24}$$

$$\text{Energy generated per annum} = \text{L.F} \times \text{Maximum demand} \times 365 \times 24$$

$$= 0.4 \times 100 \times 365 \times 24$$

$$= 350.4 \times 10^3 \text{ MWhr}$$

Result:

$$\text{Energy generated per annum} = 350.4 \times 10^3 \text{ MWhr}.$$

4. A diesel station supplies the following loads to various consumers:

Individualconsumer = 1500KW
commercialestablishment = 750KW

Domesticpower = 100KW

Domesticlight = 450KW

If the maximum demand on the station is 2500Kw and the number of KWH generated pe year is 45×10^6 ?

Determine:

Diversity factor

Annual Load factor Nov/Dec-2008

Solution

Maximum Demand $= 2500\text{KW}$

$$\text{No of KWhr generated per year} = 45 \times 10^6 \text{ Kwhr}$$

$$\text{Diversity factor} = \frac{\text{Sum of all individual maximum demand}}{\text{Maximum demand on station}}$$

$$\text{Diversity factor} = \frac{1500 + 750 + 100 + 50}{2500}$$

$$= 1.12$$

$$\text{Annual Load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$\text{Average load} = \frac{\text{Units generated per annuam}}{\text{Hours in a year}}$$

$$\text{Average load} = \frac{45 \times 10^6}{365 \times 24} = 513.699\text{KW}$$

$$\text{Annual Load factor} = \frac{513.699\text{KW}}{2500} = 0.20548 = 20.548\%$$

Result: Diversity factor $= 1.12$

Annual Load factor $= 0.20548 = 20.548\%$

5. A generating station supplied the following loads 15000KW,12000KW,8500KW,6000KWand 450KW the station has a maximum demand of 22000KW.the annual load factor of the station is 48%. Calculate,

1. The number of units supplied.

2. The diversity factor

3. The demand factor. (NOV/DEC 2017)

Solution:

Maximum Demand $= 22000\text{KW}$

$$\text{Annual Load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$0.48 = \frac{\text{Average load}}{22000}$$

$\text{Average load} = 22000 \times 0.48 = 10560\text{KW}$

KWhr Units generated per annuam $=$ Average load $\times$ Hours in a year

$= 10560 \times 365 \times 24$

No units supplied $= 92 \times 10^6\text{KWhr}$

$$\text{Diversity factor} = \frac{\text{Sum of all individual maximum demand}}{\text{Maximum demand on station}}$$

$$= \frac{15000 + 12000 + 8500 + 6000 + 450}{22000} = 1.907$$

$$\text{Diversity factor} = 1.907$$

$$\text{Demand factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$= \frac{10560}{22000} = 0.48$$

Result:

1. No units supplied $= 92 \times 10^6$ KWhr
2. Diversity factor $= 1.907$
3. Demand factor $= 0.48$

6.A generating station has the following daily load cycle;

Time(Hrs)	0-6	6-10	10-12	12-16	16-20	20-24
Load(MW)	45	35	75	20	80	50

1. Draw the daily load curve

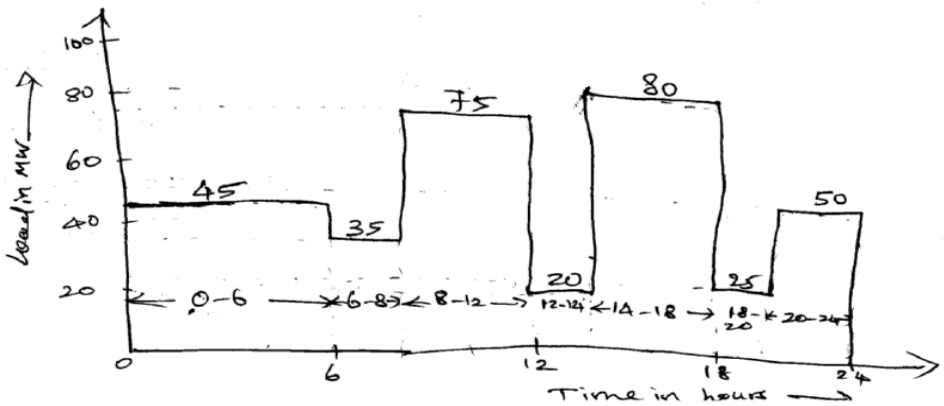
2. Draw the load duration curve

3. Load factor

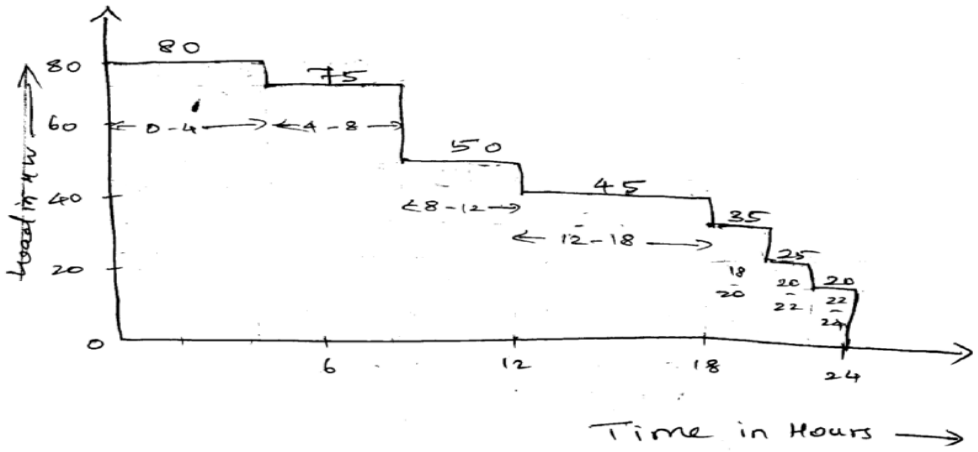
4.calculate plant capacity factor if the capacity of plant is 120MW Nov/Dec-2010

Solution:

Load curve:



Load duration curve:



$$\text{load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

Unitsgeneratedperday

$$= (80 \times 4) + (75 \times 4) + (50 \times 4) + (45 \times 6) + (35 \times 2) + (25 \times 2) + (20 \times 2)$$

$$= 1250\text{MhWhr}$$

$\text{Maximum Demand} = 80\text{MW}$

$$\text{Average load} = \frac{1250}{24} = 52.083\,\text{MW}$$

$$\textbf{Loadfactor} = \frac{52.083}{\mathbf{80}} = \mathbf{0.651OR65.1}\%$$

$$\text{Plant capacity factor} = \frac{\text{Average load}}{\text{Rated capacity of power plant}}$$

$$\text{Plant capacity factor} = \frac{52.083}{120} = 0.434 \text{ or } 43.4\%$$

Result:

$\text{Maximum Demand} = 80\text{MW}$

$\text{Unitsgeneratedperday} = 1250\text{MhWhr}$

$\text{Average load} = 52.083\,\text{MW}$

$\text{Loadfactor} = 0.651\text{OR}65.1\%$

$\text{Plant capacity factor} = 0.434 \text{ or } 43.4\%.$

7. A generating station supplies the following loads connected to it :

$\text{Industries} = 95\text{MW}$
$\text{Domesticlightingload} = 5\text{MW}$
$\text{Domesticpowerload} = 8\text{MW}$
$\text{commercial load} = 12\text{MW}$
If the maximum demand on the station is 92MW Calculate the load factor and diversity factor if the total number of units generated in a year are3×10^8
Apr/May-2011
Solution:

$$\text{Diversity factor} = \frac{\text{Sum of all individual maximum demand}}{\text{Maximum demand on station}}$$

$$\text{Diversity factor} = \frac{92 + 5 + 8 + 12}{92} = 1.272$$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$\text{Average load} = \frac{\text{Units generated per annuam}}{\text{Hours in a year}}$$

$$= \frac{\mathbf{3 \times 10^8}}{365 \times 24} = 34246.57 \text{ KW}$$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum Demand}}$$

$$= \frac{34246.57 \text{ KW}}{\mathbf{92 \times 10^3}} = 0.3722 = 37.22\%$$

Result:

$\text{Diversity factor} = 1.272$

$\text{Average load} = 34246.57 \text{ KW}$

8.A generating station has a maximum demand of 20MW,a load factor of 60% a plant capacity factor of 48% and plant use factor of 80%. Find the
(i)Daily energy produced.
(ii) Reserve capacity of the plant.
(iii)Maximum energy that could be produced daily if the plant was running all the time.
(iv)Maximum energy that could be produced if the plant when running (According to operating scheduled)were fully loaded.(Nov/Dec-2011)
Solution:
Maximum

$$\text{Maximum Demand} = 200\text{MW}$$

$$\textbf{Load factor} = \mathbf{0.6 OR 60}\ \%$$

$$\text{Plant capacity factor} = 0.48\ \mathbf{OR 48}\ \%$$

$$\text{Plant use factor} = 0.8 \textbf{ OR80 } \%$$

$$\text{Avegage load} = \text{Load factor} \times \text{Maximum Demand}$$

$$= 0.6 \times 20 = 12\text{MW}$$

(1) Daily energy produced (or)units generated per day

$$= \text{Avegage load} \times \text{Hours in a day}$$

$$= 12 \times 24 = 288 \text{ MWhr}$$

$$\text{plant capacity factor} = \frac{\text{Avegage load}}{\text{installed capacity}}$$

$$\text{installed capacity} = \frac{\text{Avegage load}}{\text{plant capacity factor}}$$

$$= \frac{12}{0.48} = 25 \text{ MW}$$

(2) Reverse capacity of the plant = installed capacity − Maximum Demand

$$= 25 - 20 = 5\text{MW}$$

(3) Energy per day corresponding to installed capacity

$$= \text{INstalled capacity} \times \text{Hours in a day}$$

$$= 25 \times 24 = 600\text{MWhr}$$

(4) Maximum energy that could be produced

$$\text{capacity according to Schedule} = \frac{\text{Actual Energy produced}}{\text{Plant use Factor}}$$

$$= \frac{288}{0.8} = 360 \text{ MWhr}$$

Result :

Daily energy produced = 288 MWhr

Reverse capacity of the plant = 5MW

Energy per day corresponding to installed capacity = 600MWhr

Maximum energy that could be produced = 360 MWhr

9. A generating station has a maximum demand of 50,000KW.calculate the cost per unit generated from the following dates .Nov/Dec-2011.

capital cost $= 95 \times 10^6$

$\mathbf{AnnualLoadfactor} = \mathbf{40}\ \%$

$\mathbf{Annualcostoffueloroil} = 9 \times 10^6$

Taxes, wages and salaries etc $= 7.5 \times 10^6$

interst and depreciation $= 12\%$

solution:

Units generated per annum

$$= \text{Maximum demand} \times \text{Annualloadfactor} \times \text{Hoursinayear}$$

$$\text{Units generated per annum} = 50000 \times 0.4 \times 365 \times 24$$

$$= 175.2 \times 10^6 \text{Kwhr}$$

$$\text{Annual fixed charges} = 12\% \text{ of capital cost}$$

$$= 0.12 \times 95 \times 10^6 = \text{Rs: } 11.4 \times 10^6$$

$$\text{Total annual running charges} = \text{Annual cost of fuel \& } oil + costoftaxesetc$$

$$= 9 \times 10^6 + 7.5 \times 10^6$$

$$= 16.5 \times 10^6$$

$$\text{Total annual charges} = \text{Annual Fixed charges} + \text{Annual running charges}$$

$$= 11.4 \times 10^6 + 16.5 \times 10^6$$

$$= \text{Rs: } 27.9 \times 10^6$$

$$\text{cost/unit} = \frac{\text{Total annual charges}}{\text{Unis generated per annum}}$$

$$= \frac{27.9 \times 10^6}{172.5 \times 10^6} = \text{Rs: } 0.16$$

$$\text{cost/unit} = 16 \text{ paise}$$

10. A power station is to supply three region of load whose peak loads are 20MW,15MW and 25MW.the annual load factor is 50% and the diversity factor of the load at the station, installed capacity suggesting number of units and annual energy supplied. Nov/Dec-2012

Solution:

$$\mathbf{Annualloadfactor} = \mathbf{50}\%$$

$$\textbf{Diversityfactor} = \mathbf{1.5}$$

$$\text{Diversityfactor} = \frac{\text{Sumofallindividualmaximumdemand}}{\text{Maximumdemandonstation}}$$

$$1.5 = \frac{20 + 15 + 25}{\text{Maximumdemandonstation}}$$

$$\text{Maximumdemandonstation} = \frac{60}{1.5} = 40\text{MW}$$

$$\text{Load factor} = \frac{\text{Avegage load}}{\text{Maximum Demand}}$$

$$\text{Avegage load} = \text{Load factor} \times \text{Maximum Demand}$$

$$= 0.5 \times 40$$

$$= 20\text{MW}$$

$$\text{Annual energy supplied or the no of units supplied} = \text{Avegage load} \times \text{Hours in a year}$$

$$= 20 \times 365 \times 24$$

$$= 175200\text{MWhr}$$

Result:

$$\text{Maximumdemand} = 40\text{MW}$$

$$\text{Avegage load} = 20\text{MW}$$

$$\text{Annual energy supplied} = 175200\text{MWhr}$$

11.A generating station has the following daily load cycle:

Time(Hrs)	**0-6**	**6-10**	**10-12**	**12-16**	**16-20**	**20-24**
Load(MW)	**40**	**50**	**60**	**50**	**70**	**40**

Draw the load curve and calculate,

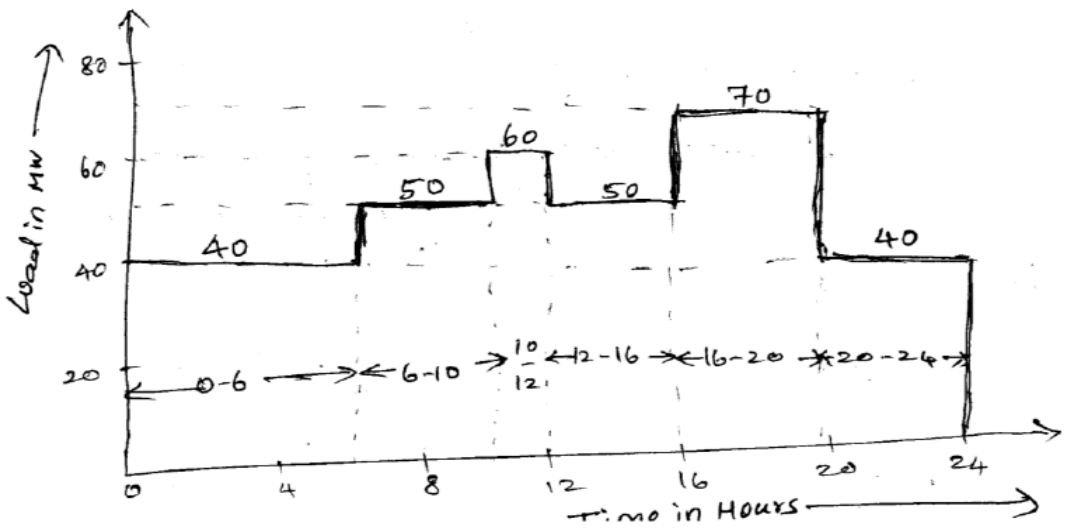
1. Maxi demand,

2. Units generated per day

3. Average load

4. Load factor **Nov-Dec-2012**

Solution:



(1)Maximumdemand = 70MW

(2)Unitsgeneratedperday

$$= (6 \times 40) + (50 \times 4) + (60 \times 2) + (50 \times 4) + (4 \times 70) + (40 \times 4)$$

$$= 1200\text{MWhhhh}$$

(3) $$\text{Average load} = \frac{1200\text{MhWhr}}{24} = 50000\text{KW} = 50\text{MW}$$

(4)Load factor $$= \frac{\text{Average load}}{\text{Maximumdemand}} = \frac{50}{70} = 0.7143 \text{ or } 71.43\%$$

12.A power supply is having the following loads:

Type of load	Maxi Demand(KW)	Diversity factor	Demand factors
Domestic	**15000**	**1.25**	**0.70**
Commercial	**25000**	**1.25**	**0.90**
Industrial	**50000**	**1.30**	**0.98**

If the over all system diversity factor is 1.5

Determine,

1.Maximum demand,2. Connected load of each type.

Solution:

1. Totalmaxidemandofloads = 15000 + 25000 + 50000 = 90000KW

systemdiversityfactor = 1.5

$$\text{maxidemand} = \frac{\text{Totalmaxidemand}}{\text{systemdiversityfactor}} = \frac{90000}{1.5} = 60000\text{KW}$$

2. Domesticload

$$\text{diversityfactorofDomesticload} = \frac{\text{Maxidomesticdemand}}{\text{systemdiversityfactor}}$$

$$\text{Maxidomesticdemand} = \text{diversityfactor} \times \text{Domesticload}$$

$$= 15000 \times 1.25 = 18750\text{KW}$$

$$\text{connecteddomesticload} = \frac{\text{Maxidomesticdemand}}{\text{sdemandfactordomesticload}}$$

$$= \frac{18750}{0.7} = 26785.72\text{KW}$$

3. commercialload

$$\text{Maxicommercialdemand} = \text{diversityfactor} \times \text{Maxicommercialload}$$

$$= 25000 \times 1.25 = 31250\text{KW}$$

$$\text{Connectedcommercialload} = \frac{\text{Maxicommercialdemand}}{\text{diversityfactor}}$$

$$= \frac{31250}{0.9} = 34722.22\text{KW}$$

3. industrialload

$$\text{Maxiindustrialdemand} = \text{diversityfactor} \times \text{Maxiindustrialload}$$

$$= 50000 \times 1.3 = 65000\text{KW}$$

$$\text{connectedindustrialload} = \frac{\text{Maxiindustrialdemand}}{\text{diversityfactor}}$$

$$= \frac{65000}{0.98} = 66326\text{KW}$$

13.A power supply is having the following loads:

Type of load	Maxi Demand(KW)	Diversity factor	Demand factors
Domestic	**10000**	**1.20**	**0.80**
Commercial	**30000**	**1.30**	**0.90**
Industrial	**50000**	**1.35**	**0.95**

If the over all system diversity factor is 1.5

Determine,

1.Maximum demand,

2. Connected load of each type.(May/June-2014)

Solution:

$$1.\ \text{Total maxi demand of loads} = 10000 + 30000 + 50000 = 90000\text{KW}$$

$$\text{system diversity factor} = 1.5$$

$$\text{maxi demand} = \frac{\text{Total maxi demand}}{\text{system diversity factor}} = \frac{90000}{1.5} = 60000\text{KW}$$

2. Domestic load

$$\text{diversity factor of Domestic load} = \frac{\text{Maxi domestic demand}}{\text{system diversity factor}}$$

$$\text{Maxi domestic demand} = \text{diversity factor} \times \text{Domestic load}$$

$$= 10000 \times 1.2 = 12000\text{KW}$$

$$\text{connected domestic load} = \frac{\text{Maxi domestic demand}}{\text{s demand factor domestic load}}$$

$$= \frac{12000}{0.8} = 15000\text{KW}$$

3. commercial load

$$\text{Maxi commercial demand} = \text{diversity factor} \times \text{Maxi commercial load}$$

$$= 30000 \times 1.3 = 39000\text{KW}$$

$$\text{Connected commercial load} = \frac{\text{Maxi commercial demand}}{\text{diversity factor}}$$

$$= \frac{39000}{0.9} = 43333.33\text{KW}$$

3. industrial load

$$\text{Maxi industrial demand} = \text{diversity factor} \times \text{Maxi industrial load}$$

$$= 50000 \times 1.35 = 67500\text{KW}$$

$$\text{connected industrial load} = \frac{\text{Maxi industrial demand}}{\text{diversity factor}}$$

$$= \frac{67500}{0.95} = 71{,}052.63\text{KW}$$

14. A peak load on the thermal power plant is 75MW. The loads having maximum demand of 35MW,20MW,15MW and 18MW are connected to the power plant. The capacity of the plant is 90MW and annual load factor is 0.53. Calculate the average load on power plant, energy supplied per year, demand factor and diversity factor. (Nov/Dec 16).

Solution:

a) Load factor $= \frac{\textbf{Average load}}{\textbf{Peak load}}$

$0.53 = \frac{\text{Average load}}{75}$

Average load $= 0.53 \times 75 =$ **39.75MW**

b) Energy supplied per year

= average load × 24×365

= 39.75 × 8760 = **348210MWh**

c) Demand factor $= \frac{\textbf{Annual peak load of the system}}{\textbf{sum of the individual maximum demand}}$

$= \frac{75}{35+20+15+18} =$ **0.852**

d) **Diversity factor** $= \frac{\textbf{sum of the individual maximum demand}}{\textbf{Annual peak load of the system}}$

$= \frac{35+20+15+18}{75} =$ **1.173**

QUESTION BANK

PART A

1. Define: load factor, utility factor, and plant operating factor, capacity factor, demand factor anddiversity factor.
2. What is the difference between demand factor and diversity factor?
3. What is 'diversity factor'? List its advantages in a power system.
4. Prove that the load factor of a power system is improved by an increase in diversity of load.
5. What is meant by load curve? Explain its importance in power generation.
6. Differentiate 'dump power', 'firm power' and 'prime power'.
7. Define 'depreciation' and explain its significance.
8. Explain the sinking fund method of calculating the depreciation.
9. Discuss the factors to be considered for, 'plant selection' for a
10. How 'load duration curve' is obtained from 'load' curve?
11. What are the principal factors involved in fixing of a tariff?

12.What do you know about environment pollution due to energy uses?
13. Explain environment pollution due to industrial emissions.
14. Explain environment pollution due to road transport.
15. Define harmful effect of emission.
16. What are the step taken for reduce air pollution?
17. Write short notes on Noise pollution and its control.
18. What is the green house gases and their effects? Explain.
19. Briefly explain fossil fuel pollution.
20. What is acid rain, explain?
21. Write short notes on stratospheric ozone depletion, Acid Fog.
22. Write on pollution due to combustion of fuel.
23. Explain how gas combustion polluted the atmosphere.
24. What do you understand by liquid fuel pollution?
25. What do you understand by solid fuel pollution?
26. What do you understand by thermal pollution, explain the bad effects of thermal pollution?
27. Explain the pollution due to nuclear power plant.
28. Explain the method to reduce the pollution.

Part- B

1.What is the cost of Electrical Generation? And its various types of cost associated with Power Generation? Ref pg.no.10

2.Explain the methods of calculating the depreciation of an electrical power plant. Ref pg.no.11

3.Explain various types of tariff system. Ref pg.no.13

4.Compare the economics of following power plants.

(i)Nuclear and thermal power plants.

(ii)gas turbine and diesel power plant. Ref pg.no.15

5.What are the fixed and operating costs of steam power plant? How are they accounted for fixing cost of electricity? (Dec 11) Ref pg.no.16

6.Write Short Notes on Air pollution in thermal power plant. Ref pg.no.22

7.Write Short Notes on water pollution in thermal power plant. Ref pg.no.23

8.Write short notes on Environmental concerns in diesel power plant. Ref pg.no.24

9.Write short notes on Environmental concerns in nuclear power plant. Ref pg.no.26

10. Explain the pollution control methods for various power plants? Ref pg.no.30

11. Write Short Notes on Nuclear Waste and Its Disposal. Ref pg.no.31

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J 3320

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2009.

Sixth Semester

Mechanical Engineering

ME 1354 — POWER PLANT ENGINEERING

(Common to B.E. (Part-Time) Fifth Semester Regulation 2005)

Time : Three hours Maximum : 100 marks

Use of standard charts and tables are allowed.

Any missing data can be assumed suitably.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Give the requirements of chain reaction.

2. Why is the maximum cycle temperature of gas turbine plant much lower than that of diesel power plant?

3. What is the necessity of draft tubes? List the types.

4. What is the significance of specific speed of hydraulic turbines?

5. Distinguish between fouling and slagging.

6. List the advantages of balanced draft system.

7. What is meant by seeding in MHD systems?

8. Mention the problems in solar thermal central receiver systems.

9. List down the nuclear waste disposal methods.

10. What are the components of tidal power plants?

PART B — (5 × 16 = 80 marks)

11. (a) (i) A gas turbine draws in air from atmosphere at 1 bar and 25°C and compresses it to 5 bar. The air is heated to 1250 K at constant pressure and then expanded through two stages in series back to 1 bar. The high pressure turbine is connected to the compressor and produces just enough power to drive it. The low pressure stage is connected to an external load and produces 82 kW of power. Calculate the mass flow of air, the inter-stage pressure of the turbines and the thermal efficiency of the cycle. Assume γ = 1.4 and Cp = 1.005 kJ/kg K for both the turbines and the compressor. Neglect the increase in mass due to the addition of fuel for burning. (8)

(ii) Explain about Velox boiler with neat sketch. (8)

Or

(b) (i) Steam enters the high pressure turbine at 12 MPa and 600°C and is condensed in the condenser at a pressure of 10 kPa. If the moisture content of steam at the exit of low pressure turbine is not to exceed 12%. Determine pressure at which the steam should be reheated and thermal efficiency of the cycle. (8)

(ii) Discuss in detail about FBC boiler. (8)

12. (a) (i) Discuss about pulverized coal handling system. (5)

(ii) Explain the working of spreader stoker. (5)

(iii) What are the factors affect the performance of electrostatic precipitator? Explain. (6)

Or

(b) (i) Calculate the height of chimney required to produce a draught equivalent to 20 mm of water if the flue gas temperature is 260°C and ambient temperature is 27°C and the stoichiometric air requirement is 18 kg per kg of fuel. Assume 50% excess air for combustion. (6)

(ii) Write short notes on the following:

(1) Requirements of surface condensers.

(2) Forced draft and induced draft cooling towers. (10)

13. (a) (i) What are the desirable properties of a good moderator? (4)

(ii) Explain about sodium cooled reactor with a neat sketch. (8)

(iii) What are the advantages and disadvantages of breeder reactor? (4)

Or

(b) (i) Discuss in detail about the factors affect which affect the selection of hydraulic turbines. (6)

(ii) How do you govern the Francis turbine? (6)

(iii) Describe — Muschel curves. (4)

14. (a) (i) Brief about the performance evaluation of diesel power plant. (4)

(ii) A cooling tower is required for a diesel power to cool 1200 litres of water at 70°C. The DBT and WBT of atmospheric air are 28°C and 23°C respectively. A forced draft tower with 75% efficiency is used for cooling. Calculate the fan power. Assume that air goes out of tower at 60°C and 90% RH. (7)

(iii) Explain about the essential components of diesel power plant. (5)

Or

(b) (i) A gas turbine draws in air from atmosphere at 1 bar and 300 K and compresses it to 6.5 bar. The air is heated to 1350 K at constant pressure and then expanded through two stages in series back to 1 bar. The high pressure turbine is connected to the compressor and produces just enough power to drive it. Assume γ = 1.4 and R = 0.287 kJ/kg K for both the turbine and compressor. Neglect the increase in mass due to the addition of fuel for burning. Calculate the following for a mass flow of 1 kg/s, the inter-stage pressure, the net power output, and the thermal efficiency of the cycle. (9)

(ii) What are the methods to improve the efficiency of the gas turbine power plants? (3)

(iii) What are the advantages of repowering cycle? (4)

15. (a) (i) From the following data, calculate the generation cost and reserve capacity of thermal power plant: Installed capacity = 175 MW; Annual load factor = 60%; Capital cost = Rs. 950 crores; Annual cost including salaries = 15% of annual cost; Rate of interest = 8.5%; Rate of depreciation = 9%; Auxiliary power consumption = 6% of power generation. (6)

(ii) Explain working of hybrid OTEC system and what are the advantages? (6)

(iii) Calculate the average power available for one tidal period if the surface area is 1,50,000 m^2 and the range of tide is 10.25 m. (4)

Or

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Question Paper Code : Q 2321

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2009.

Sixth Semester

Mechanical Engineering

ME 1354 — POWER PLANT ENGINEERING

(Common to B.E. (Part-Time) Fifth Semester Regulation 2005)

(Regulation 2004)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What factors should be taken into consideration while selecting the site for steam power plant?

2. What is the significance of Load curves?

3. State the characteristic of good ash handling plant.

4. What do you understand by the term 'Boiler draught'?

5. What is a nuclear fusion?

6. What do you mean by 'specific speed' of a turbine?

7. State the applications of diesel power plant.

8. What do you understand by a close cycle gas turbine power plant?

9. What are the advantages and limitations of tidal power generation?

10. What do you understand by the term tariff?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Draw a neat diagram of Diesel power plant and explain the essential components of the plant. (8)

(ii) Distinguish between Hydro-power plant and Thermal power plant. (8)

Or

(b) (i) What are the advantages of high pressure boilers? Discuss the guide lines for the selection of boilers for steam power plants. (6)

(ii) The daily load curve for a power plant is given by the following equation

$L = 350 + 10t - t^2$

where t is time in hours from 0 to 24 hours and L is in MW calculate :

(1) Value of maximum load and when it occurs, and

(2) Load factor of the plant.

Draw load curve and load duration curve. (10)

12. (a) (i) What are the ash handling systems? Draw a line diagram of hydraulic ash handling system for modern high capacity plants. Explain its working. (10)

(ii) Explain with the help of neat sketches the working of 'forced draft' and 'Induced draft' cooling towers. (6)

Or

(b) (i) Explain with the help of neat sketch, the working of an electro-static precipitator and give its outstanding features over other collectors. (8)

(ii) Explain with the help of neat diagram of Evaporative surface condenser and also explain its advantages. (8)

13. (a) (i) How are nuclear power plants classified? Explain how fission reaction takes place and how the chain reaction is controlled. (6)

(ii) Describe with the help of a neat sketch the construction working of a Pressurized Water Reactor (PWR). What are the advantages and disadvantages? (10)

Or

(b) (i) What is the function of surge tank in a hydro-electric plant? Explain with the help of neat diagram. (8)

(ii) The following data is available for a hydro-power plant :

Available head =140 m; catchment area = 2000 sq.km ;

Annual average rainfall = 145 cm; Turbine efficiency = 85%;

Generator efficiency = 90%; Percolation and evaporation losses = 16%.

Determine the following :

(1) Power developed.

(2) Suggest type of turbine to be used if runner speed is to be kept below 240 rpm. (8)

14. (a) (i) State and explain the factors which are required to be considered in the choice of diesel engine for a diesel power plant. (8)

(ii) List the essential components of a Gas turbine power plant and explain them briefly. (8)

Or

(b) (i) What are the different fuels that are used for gas turbine power plants? What are the most suitable fuels for gas turbine plants in a country like India? Explain. (6)

(ii) A Gas turbine unit has a pressure ratio of 6 : 1 and maximum cycle temperature of 610°C. The Isentropic efficiencies of the compressor and turbine are 0.80 and 0.82 respectively. Calculate the power output in kilowatts of an electric generator geared to turbine when the air enters the compressor at 15°C at the rate of 16 kg/s.

Take C_p = 1.005 kJ/kg K and $\gamma = 1.4$ for the compression process, and take $C_p = 1.11$ kJ/kg K and $\gamma = 1.333$ for the expansion process. (10)

15. (a) (i) Explain the working of a single basin tidal power plant. (8)

(ii) Discuss the economic loading of combined steam and hydro-plants. (8)

Or

(b) (i) Explain briefly the Block meter rate and Doherty rate. (6)

(ii) A power plant of 180 MW installed capacity has following data : (10)

Capital cost	= 120 MW
Interest and depreciation	= 12 per cent
Annual load factor	= 0.6
Annual capacity factor	= 0.5
Annual running charges	= Rs. $36*10^6$
Energy consumed by power auxiliaries	= 6 per cent

Calculate :

(1) Reserve capacity

(2) Generation capacity.

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Question Paper Code : C 1385

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2010.

Sixth Semester

Mechanical Engineering

ME 1354 — POWER PLANT ENGINEERING

(Common to B.E. (Part-Time) Fifth Semester (Regulation 2005))

Time : Three hours Maximum : 100 marks

Any missing data can be assumed suitably.

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Classify power plants on the basis of traditional use.

2. Indicate the advantage of load duration curve over load curve.

3. What is a stoker? Classify it.

4. Mention the uses of fly ash.

5. What is the function of pressuriser in a PWR?

6. Why is surge tank important in a hydro plant?

7. List down the advantages of a diesel power plant.

8. Why power generation by gas turbines is attractive these days?

9. What is the principle of operation of OTEC plants?

10. List the energy tariff types.

PART B — (5 × 16 = 80 marks)

11. (a) Discuss the advantages of combined cycle power generation. Explain the working of GT-ST combined cycle plant.

Or

(b) (i) What is a supercritical boiler? List down its merits and demerits. (8)

(ii) What is acid rain? Explain how sulphur is removed in a fluidised bed combustor. (8)

12. (a) (i) With a neat diagram, explain the operation of an electrostatic precipitator. (8)

(ii) What is a bag house? Describe the working of reverse air fabric filter. (8)

Or

(b) How does a cooling tower operate? What is an FD cooling tower? Mention its merits and demerits.

13. (a) (i) Discuss with a sketch the main characteristic features of BWR. (8)

(ii) Explain how the solid nuclear waste materials are disposed. (8)

Or

(b) Explain with a neat sketch a pumped storage hydro plant. State its advantages.

14. (a) (i) Discuss the applications of diesel electric power plants. (8)

(ii) Explain how engines are selected for diesel power plants. (8)

Or

(b) (i) Bring out the differences between closed cycle and open cycle gas turbine power plants. (8)

(ii) Discuss the effect of intercooling and reheating in a gas turbine plant. (8)

15. (a) What is tidal energy? Discuss the different types of tidal plants with neat diagrams.

Or

96

(b) (i) Calculate the cost of power generation per kWh for a power station having the following data : Installed capacity of the plant – 200 MW, Capital cost = Rs. 400 crores, Rate of interest and depreciation = 12%, Annual cost of fuel, salaries and taxation = Rs. 5 crores and load factor = 50%. (8)

(ii) Compare the economics of steam, hydro, nuclear, diesel and gas turbine power plants. (8)

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Question Paper Code : 42284

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2010.

Sixth Semester

Mechanical Engineering

ME 1354 — POWER PLANT ENGINEERING

(Regulation 2004)

(Common to B.E. (Part-Time) Fifth Semester Mechanical Engineering Regulation 2005)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. List the factors to be considered while selecting the site for hydroelectric power plant?

2. What is meant by super critical type boilers?

3. Which type of draught system is preferred for power plant? Why?

4. What are the factors that affect cooling of water in a cooling tower?

5. List the factors which go in favour of nuclear energy?

6. Mention the purpose of surge tank in a hydro electric power plant?

7. What is the duty of the air intake system in a diesel engine power plant?

8. Indicate the requirements of a gas turbine?

9. Mention the concept of solar thermal central receiver system.

10. What is the main objective of tariff?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Draw the layout of a thermal power plant and explain its principle. (8)

(ii) What are the advantages and limitations of hydel power plant? (8)

Or

(b) (i) What are the essential features of a modern high pressure boiler? (8)

(ii) Sketch and explain a pressurized FBC system. (8)

12. (a) (i) What are the advantages and disadvantages of central system of pulverized coal firing? (8)

(ii) Sketch and explain the principle of any two types of stoker. (8)

Or

(b) (i) Explain the working principle of different draught systems. (8)

(ii) What are the advantages and disadvantages of a surface condenser? (8)

13. (a) (i) How is waste disposed from a nuclear power station? (8)

(ii) Sketch and explain the working of boiling water reactor. (8)

Or

(b) (i) Explain with a neat sketch the principle of turbine speed regulation. (8)

(ii) What are the advantages and disadvantages of micro hydro power plant? (8)

14. (a) (i) What are the factors to be considered for selecting the site of a diesel engine power plant? (8)

(ii) Explain the various components used in a diesel engine power plant. (8)

Or

(b) (i) Describe the different fuels which can be burnt in a gas turbine plant. (8)

(ii) Discuss the materials which are used for gas turbine. (8)

15. (a) (i) Explain the different types of geothermal sources. (8)

(ii) What are the advantages and disadvantages of solar cell? (8)

Or

(b) (i) What are the types of tariffs in common use? Explain the flat demand rate. (8)

(ii) Explain the straight line method and sinking fund method of calculating the depreciation. (8)

Question Paper Code : 13058

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2012.

Sixth Semester

Mechanical Engineering

080120036 — POWER PLANT ENGINEERING

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Classify hydel power plants according to the quantity of water available.

2. What do you understand by once through boilers?

3. What are the uses of ash?

4. What is boiler draught?

5. What are the requirements if fission process?

6. What are critical mass and critical size of nuclear fuel?

7. List out the commonly used starting systems in large diesel engines.

8. What are the limitations of gas turbines?

9. What is the significance of load curves?

10. List the various costs which constitute the total cost of power generation.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Explain working of a high head hydro power plant giving its layout clearly. (8)

(ii) Discuss the advantages of combined operation of thermal and hydro power stations. (8)

Or

(b) (i) Explain the unique features of high pressure boilers. (8)

(ii) Enumerate the advantages of fluidized bed boilers over conventional boilers. (8)

12. (a) (i) Enumerate and explain the steps involved in coal handling. (8)

(ii) Explain the general layout of ash handling and dust collection systems. (8)

Or

(b) (i) Explain the methods of producing artificial draught. (8)

(ii) Explain the reasons for inefficiency in surface condensers. (8)

13. (a) (i) Enumerate and explain the essential components of a nuclear reactor. (8)

(ii) Give the functions and materials for control rod, moderator, reflector and biological shield. (8)

Or

(b) (i) Describe with the help of a neat sketch the construction and working of a PWR nuclear plant. (8)

(ii) List the advantages and disadvantages of nuclear power plant. (8)

14. (a) (i) Explain with a neat diagram, the working of a thermostatically controlled cooling system of diesel engines. (8)

(ii) Explain the wet and dry sump lubrication systems with neat sketch. (8)

Or

(b) (i) State the merits and demerits of gas turbine over I.C. engines. (8)

(ii) Explain the working of combined steam and gas turbine power plants. (8)

15. (a) (i) Define peak load, demand factor, load factor and plant use factor. (8)

(ii) Enumerate the various types of tariff and explain any two of them. (8)

Or

(b) A power station has to supply load as follows :

Time (hours)	0-6	6-12	12-14	14-18	18-24
Load (MW)	45	135	90	150	75

Draw

(i) load curve

(ii) load duration curve, and

(iii) choose suitable generating units and its operation schedule to supply the load. (16)

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Reg. No. :

Question Paper Code : 11538

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Seventh Semester

Mechanical Engineering

ME 2403/ME 73/ME 1353 – POWER PLANT ENGINEERING

(Regulation 2008)

(Common to PTME 2403 Power Plant Engineering for B.E. (Part-Time) Mechanical Engineering – Seventh Semester – Regulation 2009)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Mention a few characteristics of Diesel Power plant.
2. What are the advantages of high pressure boiler?
3. What are the principles of stokers?
4. What are the advantages of Pulverized coal?
5. What is the difference between fission and fusion?
6. On what basis hydraulic turbines are selected?
7. What are the applications of Gas turbine power plants?
8. What is Reheating and Regeneration of gas turbine?
9. What is fixed and operational cost of power plants?
10. List the types of tariffs to calculate energy rate.

PART B — (5 × 16 = 80 marks)

11. (a) What is the difference between Velox and Loffler Boiler? Explain with a neat sketch.

Or

(b) (i) Draw and explain the working of Combine Power cycle plants. (8)

(ii) What is the basis for selecting a site for hydro power plants? Explain. (8)

12. (a) Explain with a neat sketch of

(i) Ash handling by Hydraulic Systems. (8)

(ii) Forced draught and induced draught cooling tower. (8)

Or

(b) (i) Explain with a neat sketch working of a balanced draught chimney. (8)

(ii) Explain different types of Solid fuels used for generating steam. (8)

13. (a) (i) Explain with a neat sketch part of a nuclear reactor. (8)

(ii) What are the advantages of boiling water reactor? Explain with a neat sketch. (8)

Or

(b) (i) What are the essential elements of hydro power plant? Explain with a neat sketch. (8)

(ii) Write a short note on Governing of steam Turbine. (8)

14. (a) Draw and explain Air intake system and Exhaust system of a diesel power plant.

Or

(b) (i) What are the advantages and disadvantages of gas turbine power plant? Explain. (8)

(ii) What are the elements of Gas turbine power plants? Explain. (8)

15. (a) (i) Draw and explain working of an Open OTEC Cycle power plant. (8)

(ii) Explain with neat sketch working of a Distributed (Parabolic) trough Solar Power Plant. (8)

Or

(b) (i) Compare principle characteristics of various power plants. (8)

(ii) The maximum demand of a power station is 80000KW and daily load is described as follows:

Time (hrs)	0–6	6–8	8–12	12–14	14–18	18–22	22–24
Load (MW)	40	50	60	50	70	80	40

(1) Determine the load factor of power station and draw the Load duration curve. (4)

(2) What is the load factor of standby equipment rated at 25 MW that takes up all load in excess of 60 MW? (4)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 31046

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2013.

Sixth Semester

Mechanical Engineering

080120036 — POWER PLANT ENGINEERING

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. List out the conventional power plants.

2. What are the purposes of a hydro project?

3. What is meant by 'over feed' and under feed' principles of firing coal?

4. What is the role played by 'cooling towers' in steam power plant?

5. What is a chain reaction? How is it controlled?

6. List the various parts of a nuclear reactor.

7. What is the main objective of supercharging?

8. What are the applications of gas turbine?

9. What is the difference between demand factor and diversity factor?

10. What is meant by load curve?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Discuss the essential features of a water-power plant. (8)

(ii) Discuss the factors considered in selecting a prime-mover for a hydro-electric power plant. (8)

Or

(b) (i) Describe, giving a neat sketch, the construction and working of a Lamont boiler. (8)

(ii) Discuss combined steam and gas turbine power plant. (8)

12. (a) (i) Make neat sketch and explain the working of Chain grate stoker. (8)

(ii) State the advantages and disadvantages of pulverised fuel firing. (8)

Or

(b) (i) Describe the operation of a balanced draught system. (8)

(ii) Discuss the advantages, disadvantages and requirements of a surface condenser. (8)

13. (a) (i) Discuss the various factors to be considered white selecting the site for nuclear power station. (8)

(ii) Describe a fast breeder reactor. (8)

Or

(b) (i) What is meant by uranium enrichment? Describe some methods of Uranium enrichment. (8)

(ii) Discuss the factors which go in favour of nuclear power plant as compared to other types of power plants. (8)

14. (a) (i) Write a note on fuel system of diesel power plant. (8)

(ii) List the main functions of a lubricant and the properties of a good lubricant. (8)

Or

(b) (i) Write a note on the gas turbine starter. (8)

(ii) Explain how "reheating" improves the thermal efficiency of a simple open cycle gas turbine plant. (8)

15. (a) (i) Define 'depreciation' and explain its significance. (8)

(ii) A hydro power plant is to be used as peak load plant at an annual load factor of 30%. The electrical energy obtained during the year is 750×10^5 kWh. Determine the maximum demand. If the plant capacity factor is 24% find reserve capacity of the plant. (8)

Or

(b) (i) Discuss the requirements of tariff. (6)

(ii) A steam power station has an installed capacity of 120 MW and a maximum demand of 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annual expenses on salary bill of staff and other overhead charges excluding cost of coal are Rs. 50×10^5. The power station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4×10^5. If the rate of interest and depreciation is 10% determine the cost of generating per kWh. (10)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 41046

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Sixth Semester

Mechanical Engineering

080120036 — POWER PLANT ENGINEERING

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What do you understand by water hammer?
2. What are the advantages of combined cycles?
3. What is the use of electrostatic precipitator?
4. What is the mechanism of pulverized fuel firing system?
5. Explain the term nuclear fission.
6. What is the function of moderator and give examples?
7. What is the use of regenerator?
8. What is meant by reheating combustion chamber?
9. What are the various types of load?
10. What are the elements of fixed and operating costs?

PART B — (5 × 16 = 80 marks)

11. (a) Describe the working of a "pumped storage plant" and discuss its importance as a peak load plant.

Or

(b) What are auxiliaries of a hydro —power plant, and what methods of drives are employed for these? Discuss the advantages and disadvantages of each method.

12. (a) Name the various methods of ash handling. Describe the pneumatic system of ash handling. Why it is essential to quench the ash before handling?

Or

(b) Draw the neat diagram of hyperbolic cooling tower and discuss its merits and demerits.

13. (a) How are nuclear reactor classified? Describe some common types of reactors used for electric power plants. Discuss fast breeder reactor.

Or

(b) How waste is disposed off in a nuclear power station? What are the main difficulties in handling radioactive waste?

14. (a) Draw a neat sketch of a diesel power plant showing all the systems.

Or

(b) What are the fuels used in gas turbine plants and what fuel characteristics suit such plants best? Discuss the recent trends to use solid fuels in such plants.

15. (a) Enumerate various types of tariff and explain any two of them.

Or

(b) The annual peak load on a 30MW power station is 25 MW .The power station supplied loads having maximum demands of 10 MW, 8.5 MW, 5 MW and 4.5 MW. The annual load factor is 45%. Find

(i) Average load

(ii) Energy supplied by year

(iii) Diversity factor

(iv) Demand factor.

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Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 91439

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2014.

Fourth Semester

Electrical and Electronics Engineering

EE 2252/EE 43/EE 1252/080280027/10133 EE 403 — POWER PLANT ENGINEERING

(Regulation 2008/2010)

Time : Three hours Maximum : 100 marks

(Use of steam tables and Mollier Chart is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Explain basic Thermodynamics cycles.

2. What are the methods of controlling fans? What are the disadvantages of FD fans?

3. Write about types of Turbines.

4. What is a surge tank? Why it is important in Hydro power plant?

5. What is a nuclear fission?

6. What you understand by Radioactive decay?

7. What are the main differences in work output and thermal efficiency of Gas Turbine?

8. What type of cycle is used in Gas Turbine?

9. What are the types of solar collector?

10. Give example of geothermal resourses?

PART B — (5 × 16 = 80 marks)

11. (a) Explain the types of coal handling systems? Write any one method with a neat flow diagram.

Or

(b) Explain with a neat sketch about the following :

(i) Super heater

(ii) Deaerator

12. (a) Write about selection of Water Turbine? Explain any one Turbine with neat sketch used in Hydro electric power plants.

Or

(b) Explain with neat sketch pumped storage plant. What are its advantages?

13. (a) Write about principles of nuclear energy. List out the various power plants station in India. With neat sketch explain any one.

Or

(b) Explain the characteristic features of BWR. What do you mean by internal and external circulation.

14. (a) With a neat sketch explain Diesel engine power plant component layout. And also list out merits and demerits.

Or

(b) Explain the effect of regeneration in gas turbine plant. Give the specific advantage and disadvantage of gas turbine plant for a utility system.

15. (a) What is meant by Thermoelectric power generation and Thermionic power generation. Discuss in detail with suitable sketch.

Or

(b) Write short notes on:

(i) Fuel cell

(ii) MHD power generation

(iii) OTEC

(iv) Tidal power plants.

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Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 71502

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Fourth Semester

Electrical and Electronics Engineering

EE 2252/EE 43/EE 1252/080280027/10133 EE 403 — POWER PLANT ENGINEERING

(Regulation 2008/2010)

Time : Three hours Maximum : 100 marks

(Use of steam tables and Mollier Chart is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define pH. Why high pH value is preferred to prevent the corrosion?

2. What is the function of super heaters in a thermal plant?

3. What are mini and micro hydel plants? Why are they in the news recently?

4. What are the different factors to be considered while selecting the site for hydro electric power plants?

5. What do you understand by moderation? Why it is essential?

6. Distinguish between fertile and fissile materials.

7. What do you mean by super charging of diesel engines?

8. Why is gas turbine best suited for peak load?

9. Enumerate the factors affecting the suitability of the site for the tidal power plant.

10. What is the principle of operation of MHD generators?

PART B — (5 × 16 = 80 marks)

11. (a) Briefly discuss the Loeffler boiler and enumerate its advantages.

Or

(b) Describe with neat sketches the operation of the following condensers.

(i) Jet Condenser

(ii) Evaporative condenser.

12. (a) Classify the hydro electric plants according to availability of head and nature of load.

Or

(b) Discuss the pumped storage hydel plant with neat sketches and high light their advantages.

13. (a) Describe the general components of a nuclear reactor.

Or

(b) Draw the diagrams of PWR and BWR and explain the advantages and disadvantages. What are the conditions which prefer PWR over BWR and vice versa?

14. (a) With the layout of a diesel power plant, explain its working and compare the difference between thermal and diesel plants.

Or

(b) An open cycle gas turbine uses heavy oil is fuel. The maximum pressure and temperature in the cycle are 5 bar and 650°C. The pressure and temperature of air entering into the compressor are 1 bar and 27°C. The exit pressure of the turbine is also 1 bar. Assuming isentric efficiencies of compressor and turbine to be 80% and 85% respectively, find the thermal efficiencies of the cycle. The overall A: F ratio used is 60:1.

Take C_p (for air and gas) = 1.004 KJ/kg°C and γ (for air and gas) = 1.4.

If the plant consumes 5 kg of fuel/sec, find the power generating capacity of the plant.

15. (a) Briefly state the advantages and thermo electricity generation to electricity generation by solar PV system. Explain the construction and working of parabolic solar collectors.

Or

(b) Explain the working of the vertical axis windmill mentioning special arrangements of the blades. Also state how the volatility in wind power is managed in practice.

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Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 27380

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fifth Semester

Electrical and Electronics Engineering

ME 6701 — POWER PLANT ENGINEERING

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is meant by super critical boiler? IAT - I (11)
2. What is pulveriser and why it is used? IAT - I (12)
3. Mention the major difference between otto cycle and diesel cycle.
4. Why power generation by gas turbine is more attractive than other turbines?
5. List the function of control rods.
6. How do you cater for safety of nuclear power plant? Model 15 b (ii)
7. Mention the various advantage of wind power.
8. What are the limitations of tidal power plant?
9. What is the significance of load curve?
10. What are the equipment used to control the particulates?

PART B — (5 × 16 = 80 marks)

11. (a) Write short notes on : 11(b) IAT - I
    (i) Ash handling system. (8)
    (ii) Different draught systems. 12(b) IAT-I (8)

Or

(b) Explain with a neat sketch the working of a thermal electric power plant station and discuss the function of major components in it. (16) 11(A) IAT-I

12. (a) Explain the working of open cycle and closed cycle gas turbine power plant and discuss its advantages and disadvantages. (16)

Or

(b) (i) Explain in detail about the construction and working of IGCC. (10) (13) IAT-II

(ii) Draw and explain PV and TS diagrams of Brayton cycle. (6) (8) IAT-II

13. (a) Explain with a neat diagram the various parts of nuclear power plant and mentioning the function of each part. (16) (4) IAT-III

Or

(b) (i) Explain CANDU reactor with neat sketch. Give its advantages and disadvantages. (8)

(ii) Explain what is chain reaction in connection with a nuclear reactor. (8) (3) IAT-III

14. (a) (i) Draw a schematic diagram of a hydro plant and explain the operation. (10) 11 a (i) Model

(ii) Write a short note on Bio energy. (6) (13) b (i) Model

Or

(b) (i) Briefly explain solar PV system. (8) (12) b (ii) Model

(ii) What are the various kinds of fuel cell and explain the working of anyone? (8) (13) b (ii) Model

15. (a) (i) Explain the analysis of pollution from thermal power plants. (10) 15(b) Model

(ii) Elucidate the objectives and requirements to tariff and general form of tariff. (6) 13(a) Model

Or

(b) (i) Write short note on Nuclear waste disposal. (8) 15(b) Model

(ii) A central power station has annual factors as follows. Load factor = 60%, Capacity factor = 40% and use factor = 45%. Power station has a maximum demand of 15,000 KW. Determine the annual energy production, reserve capacity over and above peak load and hours per year not in service. (8) 14 a (ii) Model

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Reg. No. AUHIPPO.COM*

Question Paper Code : 80670

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2016.

Fifth Semester

Electrical and Electronics Engineering

ME 6701 — POWER PLANT ENGINEERING

(Common to Seventh Semester Mechanical Engineering (Sandwich and Mechanical Engineering))

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What do you understand by the term boiler draught?
2. Define steam rate and heat rate.
3. What is reheating and regeneration of gas turbine?
4. Name the various "gas power cycles".
5. What is critical mass of nuclear fuel?
6. Why shielding is necessary in nuclear power plants?
7. What is biogas? Give the advantages.
8. List the difference between Francis and Kaplan turbine.
9. What is main objective of tariff?
10. Define plant use factor.

PART B — (5 × 16 = 80 marks)

11. (a) Draw a general layout of steam power plant with neat diagram and Explain the working of different circuits. (16)

Or

(b) Explain the following with neat diagram :

(i) Benson boiler. (8)

(ii) Anyone type of cogeneration power plant. (8)

12. (a) Discuss the essential components of the diesel power plant with neat layout. (16)

Or

(b) (i) Derive an expression for the work ratio using Brayton cycle. (8)

(ii) Discuss the working of anyone type of combined cycle power plant. (8)

13. (a) (i) Explain CANDU(Canadian-Deuterium-Uranium) reactor with neat diagram also mention its merits and demerits. (10)

(ii) Discuss about the safety measures adopted in modern nuclear plants. (6)

Or

(b) Explain the construction and working of nuclear power plant with a layout. (16)

14. (a) (i) Explain the construction and working of fuel cell also mention its merits and demerits. (12)

(ii) List the advantages and disadvantages of wind Energy system. (4)

Or

(b) Explain the layout of hydroelectric power plant with neat diagram. (16)

15. (a) Explain the methods to control pollution in thermal and nuclear power plants. (16)

Or

(b) (i) Explain site selection criterion of hydro power plant. (8)

(ii) A Peak load on the thermal power plant is 75 MW. The loads having maximum demands of 35 MW, 20 MW, 15 MW and 18MW are connected to the power plant. The capacity of the plant is 90 MW and annual load factor is 0.53. Calculate the average load on power plant, energy supplied per year, demand factor and diversity factor. (8)

Reg. No. :

Question Paper Code : 50886

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2017
Fifth/Seventh Semester
Mechanical Engineering
ME 6701 – POWER PLANT ENGINEERING
(Regulations 2013)
(Common to Mechanical Engineering (Sandwich)/Electrical and Electronics Engineering)

Time : Three Hours | Maximum : 100 Mar

Answer ALL questions.
Use of Steam Table is permitted.

PART – A (10×2=20 Mark

1. Why majority of coal based thermal power plants are located near Seashore ?
2. Reason out why Cogeneration is quite viable in Sugar industries compared to that in other industries.
3. Justify : Auxiliary Power Consumption of Brayton Cycle is almost twice that of Rankine Cycle despite the thermodynamic processes adopted are similar.
4. State the significance of Load Factor and Capacity Factor of a Gas based Power Plant.
5. Define "electron Volt" with reference to Nuclear Power Plants.
6. Give typical examples for Control Rods.
7. Define Tidal Range (R).
8. Name 2 types of Geothermal Energy Deposits.
9. Define 'Green House Effect'.
10. How 'smog' is defined ?

(5×13=65 Marks)

PART – B

11. a) The following data refer to a simple Steam Power Plant. (13)

No.	Location	Pressure Bar	Quality/Temp°C	Velocity m/s
1	Turbine Inlet	60	380	..
2	Condenser Inlet	0.1	0.90	200

Calculate :

- Power Output of the Turbine
- Heat Transfer Rate in Boiler and Condenser
- Quantity of Cooling Water circulated.

(OR)

b) i) With a neat diagram explain the function of FBC Boilers. (6)

ii) Super Critical Boilers (7)

12. a) i) Enlist the advantages and disadvantages of a Diesel Engine Power Plant. (6)

ii) Compare the merits and demerits of open and closed cycle gas turbine power plant. (7)

(OR)

b) A 4.5 MW gas turbine generating set operates with two compressor stages. The overall pressure ratio is 9 : 1. The high pressure turbine drives the compressor while the low pressure turbine drives the generator. The temperature of gases at entry to the HP turbine is 625°C. The exhaust gases leaving the LP turbine are passed through a heat exchanger to heat the air leaving the HP stage compressor. The compressors have equal pressure ratios and intercooling is complete between the stages. The air inlet temperature is 20°C. The isentropic efficiency of each compressor stage is 0.8 and that of each turbine stage is 0.85. The heat exchanger thermal ratio is 0.8. Assume a mechanical efficiency of 93% for both power shaft and compressor turbine shaft. Neglecting other losses, compute

- Thermal Efficiency
- Work ratio of the plant
- Mass flow rate [Take Cp = 1.0 kJ/kg K, γ = 1.4 for air
  Cp = 1.15 kJ/kg K, γ = 1.33 for exhaust gases] (13)

13. a) Compare the working, merits and demerits of P W R and B W R. (13)

(OR)

b) i) What is CANDU Type Reactor ? Explain with a neat sketch its main features. (8)

ii) Name the 4 reactions involving Deuterium in a fusion reactor. Which one is achieved quite early ? (5)

14. a) "Solar Thermal Power cycles can be broadly classified into Low, Medium and High temperature cycles". Elaborate this statement with suitable examples and relevant sketches. (13)

(OR)

b) i) The wind velocity is 10 m/s at 22°C. Turbine diameter is 10 m. The wind machine operates at 35 rpm at a peak efficiency of 40%. Compute the following : (6)

- Total power density of wind stream.
- Actual power density.
- Turbine power output.

ii) Describe the energy generation cycle of 'Single Basin Single Effect' and 'Single Basin Double Effect' systems. (7)

15. a) List various pollutants released by the coal based thermal power plants and detail the techniques adopted to mitigate them. (13)

(OR)

b) i) Indicate and discuss any 4 methods adopted for the disposal of radioactive waste materials. (7)

ii) A generating station supplies four feeders with maximum demands (in MW) 16, 10, 12 and 7. The overall maximum demand of the station is 20 MW and the annual load factor is 45%. Calculate the diversity factor and number of Units generated annually. (6)

PART – C

(1×15=15 Marks)

16. a) i) Develop the procedure you would adopt to establish the unit cost of power generation from coal, solar and wind based power generation systems (Hint : Life cycle cost analysis technique). (8)

ii) Draw the Schematic of Anderson cycle based on OTEC and discuss it. (7)

(OR)

b) i) Explain the terms : i) Breeding ratio ii) Converter iii) Doubling. (8)

ii) What is tariff ? Discuss with suitable examples of two part tariff and three part tariff. (7)

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Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 41417

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2018
Fifth/Seventh Semester
Mechanical Engineering
ME 6701 – POWER PLANT ENGINEERING
(Common to Mechanical Engineering (Sandwich)/Electrical and Electronics Engineering)
(Regulations 2013)

Time : Three Hours | Maximum : 100 Marks

Answer ALL questions.

PART – A (10×2=20 Marks)

1. What is a super critical boiler ?
2. What are binary cycles ? Give examples.
3. Draw the P-V diagram of dual cycle.
4. What are the applications of gas turbine power plants ?
5. List out the important components of a nuclear reactor.
6. What are breeder reactors ?
7. How are winds formed ?
8. What is a fuel cell ?
9. Define utility factor.
10. What are chronological load curves ?

PART – B (5×13=65 Marks)

11. a) i) Discuss the various steps involved in coal handling systems. (5)
    ii) Briefly discuss the commonly used ash handling systems. (8)

    (OR)

    b) Explain the working and advantages of a fluidized bed combustion system. (13)

12. a) Describe the functions and types of fuel injection systems. (13)

    (OR)

    b) i) Write a brief note on starting systems of gas turbine. (5)
    ii) With the help of neat diagram, explain the working of combined gas turbine and steam turbine plant. (8)

13. a) i) Write a note on nuclear fuels. (5)

ii) Write the points to be considered for selecting sites for nuclear power plant. (8)

(OR)

b) Explain the working of a pressurized water reactor with a schematic diagram. (13)

14. a) i) Explain briefly the essential features of hydroelectric power plant. (8)

ii) State the advantages of inward flow reaction turbine over outward flow reaction turbine. (5)

(OR)

b) i) Explain the operation of a fixed dome type digester biogas plant. (6)

ii) Describe the working of hydrogen-oxygen fuel cell. (7)

15. a) i) What are the basic requirements of energy tariffs ? (5)

ii) Explain the elements of operating expenditure of a power plant. (8)

(OR)

b) Determine the thermal efficiency of a steam power plant and its coal bill per annum using the following data :
Maximum demand = 24000 kW, Load factor = 40%, Boiler efficiency = 90%
Turbine efficiency = 92 %, Coal consumption = 0.87 kg/Unit
Price of coal = Rs. 280 per tonne. (13)

PART – C (1×15=15 Marks)

16. a) A 2-cylinder C.I. engine with a compression ratio 13:1 and cylinder dimensions of 200 mm × 250 mm works on two stroke cycle and consumes 14 kg/h of fuel while running at 300 rpm. The relative and mechanical efficiencies of engine are 65% and 76% respectively. The fuel injection is effected upto 5% of stroke. If the calorific value of the fuel used is given as 41800 kJ/kg, calculate the mean effective pressure developed. (15)

(OR)

b) A four-stroke diesel engine has a piston diameter of 16.5 cm and a stroke of 27 cm. The compression ratio is 14.3, the cut-off a 4.23% of the stroke and the mean effective pressure 4.12 bar. The engine speed is 264 rpm and the fuel consumption is 1.076 kg of oil per hour, having a calorific value of 39150 kJ/kg. Calculate the relative efficiency of the engine. (15)